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National Research Council of Canada

DEVELOPMENT OF DESIGN PARAMETERS FOR PEAT SLURRY PUMPING AND PIPELINE TRANSPORT

May 25, 1985

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ABSTRACT

Monenco was involved in an earlier assignment for the National Research Council of Canada (NRC) to review alternative wet peat mining systems. The intent of the earlier project was to develop parallel investigations in the peat mining sector to complement the extensive work being carried out on various peat processes which accept peat feedstock in slurry form. As a logical follow-up to the earlier general review of mining technology, NRC decided to sponsor specific studies on peat slurry rheology, since little or no information was available on the behaviour of peat slurries outside of the USSR, where a wealth of knowledge has existed based on over forty years of industrial-scale peat slurry pumping practice.

The current work is the first phase of a multi-phase program. This study reports on the relationship between North American and USSR peat classification systems, the USSR laboratory methods of determining degree of decomposition and the peat slurry viscosity, and methods of calculating the main peat slurry pumping and pipelining parameters based on the principal characteristics of peat from samples collected both in Canada and New York State.

The following phases of work are expected to include:

- design and construction of a peat slurry pump/macerator; and
- actual field trials of peat slurry pumping and pipeline transport (including mining).

RÉSUMÉ

Monenco a participé, dans le cadre d'un projet antérieur, à l'étude de nouveaux systèmes d'extraction de la tourbe humide. Le but du premier projet était de conduire des études parallèles dans le domaine de l'extraction de la tourbe pour compléter les travaux détaillés menés sur divers procédés industriels utilisant la tourbe sous forme de bouillie comme matière première. Pour donner suite à l'étude générale des techniques d'extraction, le CNRC a décidé de subventionner des études spécifiques sur la rhéologie des bouillies de tourbe car on ne possédait pratiquement pas de données sur ces bouillies, en dehors de l'URSS qui dispose d'une information très riche basée sur plus de quarante années de pratique industrielle du pompage des bouillies de tourbe.

Le travail actuel constitue la première phase d'un programme multiphase. On compare les systèmes nord-américain et soviétique de classification de la tourbe, on présente les méthodes expérimentales utilisées en Union Soviétique pour déterminer la degré de décomposition et la viscosité des bouillies de tourbe et on présente des méthodes de calcul des principaux paramètres de pompage et de transport par pipeline des bouillies de tourbe. Ces paramètres sont basés sur les principales caractéristiques d'échantillons de tourbe recueillis au Canada et dans l'état de New York.

Les phases suivantes du programme devraient comprendre

- la conception et la construction d'une pompe et d'un macérateur de bouillie de tourbe, et

- des essais sur le terrain de pompage et de transport par pipeline de bouillie de tourbe (y compris l'extraction).

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INTRODUCTION

Wet peat mining and the industrial use of peat mined in this manner have been carried out only to a limited extent outside the USSR. Rather than to "re-invent the wheel," Monenco recommended using information based on the more than forty years of previous Russian experience on peat slurry pumping and pipeline transport, as a basis for studies into the development of a suitable peat slurry pumping technology for Canadian conditions.

Since little or no information was determined to exist in the west on peat slurry rheology, it was recommended that some basic rheological investigations on North American peat types be conducted. Aside from the pure pumping and pipelining of a peat slurry, it was also readily apparent that an important element in the overall process was the peat mining system and the method of preparation of the peat slurry.

In order to calculate the main pumping and pipelining parameters it was necessary to obtain detailed information on the peat slurry characteristics (such as peat type, degree of decomposition, ash content, pH, etc.), solids concentration, viscosity, flow velocity, etc. Studies including laboratory testing, on some of the above characteristics are described. Calculation of the optimal solids concentration, maximum pump capacity and pumping distance and minimum pipeline diameter included, not only the basic rheological information on the peat slurry, but also consideration of the in-situ solids content of the peat deposit and the amount of water added through the operation of the water jets during mining.

The statement of work for the project outlines the main objectives:

Task 1

Peat Sample Collection (inc. characterization and analyses)

- Collect peat samples from a number of different peatlands to obtain representative samples of Canadian fuel peats for laboratory testing. For this purpose, samples were to be obtained from four peatland areas.

- Translate the USSR peat type classification system and classify the Canadian peat samples according to the USSR classification system.

- Examine the existing information to determine the possibility of correlation between the von Post and the USSR system.

- Analyse the laboratory test results.

Task 2

Degree of Decomposition

- Outline the USSR centrifuge method to determine the degree of decomposition.

- Select and/or fabricate laboratory apparatus to perform the tests.

- Describe the method, the results of the tests performed and assess and review the problems encountered in carrying out the tests, and the reproducibility of the method.

Task 3

Peat Slurry Viscosity

- Select and review commercially available North American viscometers.

- Translate sufficient information and provide the USSR peat institute viscometer design and specification for duplication of tests.

- Test several peat samples by the USSR viscometer and compare results between the North American and USSR viscometers; characterize peat slurry viscosity values at varying applied rotational speed of viscometers for different types of peat, degree of humification, solids concentration, temperature and degree of macerating.

- Discuss the method of analysis.

- Compare the USSR viscometer with commercially available North American units in terms of reproducibility, ease of operation and the results generated.

- Correlate the North American and USSR peat slurry viscosity values.

Task 4

Calculating Methodologies

- Develop methods to calculate and predict some of the major pumping parameters, such as, maximum pump capacity, optimum solids concentration, maximum single-stage pumping distance and minimum pipeline diameter.

- Develop and describe the computer program used to increase the speed and accuracy of computations for two graphic analytical methods.

- Develop and describe the botanical spectrum method for calculating the optimum peat slurry solids content.

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

1. The preliminary work carried out for this study indicates that the North American peats and peatland types have the same characteristics as do the Russian. In fact, a few laboratory tests on North American samples reveal that the North American peat and peatland types fit quite well into the Russian system. Therefore it has been deduced that the correlation of North American peat and peatland types with the Russian is positive, and as well, that the characteristics of the similar peat types are close. However, due to the lack of a sufficient statistical background, the positive results given in Part 3 must still be regarded as preliminary and will have to be confirmed by a larger sample population and practical pumping tests.

2. To our knowledge, all recently published work which includes information on the degree of humification (decomposition) of North American peats uses field methods (such as von Post) for their determination. For purposes of the present study, it was necessary to duplicate the USSR laboratory method for degree of decomposition testing in order to obtain comparable results, since all the Russian degree of decomposition data was determined by this method.

   The laboratory method was successfully applied to Canadian and New York peats, and the information obtained on this peat characteristic can be used in the design of wet peat mining systems using the "hydropeat" type of equipment.

3. It is possible to compare the degree of decomposition and viscosity tests on North American and USSR peat types (with similar qualitative characteristics) since the testing was carried out using the same design of laboratory equipment and the same procedures in both cases.

4. The following viscosity correlations were determined from the laboratory testing:

a) between the qualitative peat characteristics (peat type, degree of decomposition, ash content) and slurry viscosity;

The various types of peat have their own unique viscosity values depending on their composition (chemical and physical) which is determined by the peat forming plants and the environment in which the peat is formed. The highest viscosity results were obtained on peats with low degree of decomposition, such as "sphagnum medium" or "sphagnum mixed" with average 10-15% degree of decomposition (or von Post H2-H4).

The viscosity decreases with increasing degree of decomposition. The laboratory testing program did not include studies of the relationship between ash content and peat viscosity since the effects of ash content and degree of decomposition on peat viscosity are interdependent.

The correlation between North American and USSR peat slurry viscosity values for peats with different qualitative characteristics were investigated. A solids concentration range of 4% to 6% (solids by weight) is expected for slurry pumping of Canadian peats using "hydropeat" equipment. The results should be regarded as preliminary since sufficient statistical data has not been accumulated and practical pumping tests have yet to be carried out.

b) between peat slurry solids content and viscosity;

The viscosity of a peat slurry decreases in proportion to decreasing solids content, and vice versa.

c) between effects of maceration of peat slurry and peat slurry viscosity;

The viscosity of a peat slurry decreases with increasing degree of maceration, i.e., the viscosity will decrease when the amount of "processing" of the peat slurry is increased. It appears that for high viscosity peats (highmoor peat), the influence of maceration is more significant than for the less viscous (lowmoor peat) peat slurries.

d) between peat slurry temperature and viscosity;

The viscosity of a peat slurry decreases with increasing slurry temperature, i.e., the lower the slurry temperature, the higher its viscosity.

5. Prior to carrying out the present work, an intensive review of existing information on peat slurry rheology showed virtually no information existing in the west, particularly related to actual peat slurry pumping system design. A 1982 engineering feasibility study on wet peat mining carried out by a major engineering firm actually assumed that peat slurry would behave as a pulp and paper slurry, and based their subsequent extraction system design on this assumption. In contrast, wet peat mining by the 'hydropeat' method had been carried out for many decades in the USSR, and it was determined that the information available from this source would be a useful starting point for study of potential wet peat mining systems suited to North American peat and peatland conditions.

6. Methods of calculating the main peat slurry pumping and pipelining parameters (such as solids concentration, pump capacity, pipeline length, pipeline diameter, system resistance, etc.) are presented based on the previous USSR information. The methods

take into account the dependency of the various peat slurry pumping parameters on the peat characteristics (such as peat type, degree of decomposition, ash content, etc.). As well, a system optimization calculation was made which takes into consideration both the hydraulic and mining aspects, such as the dilution caused by the hydromonitors in breaking down the peat face and required for flow of solids to the pump, factors which compete against the need to maintain high slurry concentration for maximum peat production. Two computer programs were developed by Monenco to increase the speed and accuracy of the computations and example calculations are included in the report.

The calculating method includes the pumping characteristic of the "hydropeat" peat slurry pump/macerator, which was specially designed for wet peat mining applications and includes several unique features such as a macerator section and an external propeller.

7. An actual field pumping test is recommended (using a modified USSR style design of peat slurry pump) to check the calculating methods for the peat slurry pumping system design. Solids concentration values achieved during the field tests can be determined and compared with the predicted values from laboratory testing and the computer calculations. Calculated values of optimum slurry solids concentration and the other pumping and pipeline parameters (pump capacity, pressure losses, pumping distance, etc.) can be compared with the actual field test results achieved from a recommended industrial-scale pumping and pipeline test system. The field tests can also serve as a check on the USSR method for predicting optimal solids content of a peat slurry using the "botanical spectrum" method.

To carry out the slurry pumping test, it is recommended to construct a peat slurry pump/macerator with similar characteristics to the previous latest USSR model.

8. For practical mining purposes, experience has shown that application of the "hydropeat" wet peat mining technology requires a peat deposit with a minimum degree of decomposition of 15%, and a peat thickness of at least 2 m.

PART 1

COLLECTION, CHARACTERIZATION AND ANALYSIS OF PEAT SAMPLES

1.1 A USSR PEAT AND PEATLAND TYPE CLASSIFICATION SYSTEM

Because almost all of the available data on peat rheology (viscosity, solids content etc.) is based on the Soviet information[1], a description of the peat and peatland classification system used in the USSR for slurry pumping is given. This system is based on a classification of peatlands according to their genesis on a trophic basis which was originally developed and widely used in central and northern Europe. In this system, the peatlands are divided into eutrophic lowmoors (German Niedermoor), intermediate mesotrophic transition moors (German Übergangsmoor) and oligotrophic highmoors (raised bogs, German Hochmoor). (The German terms are referred to as it appears that the corresponding Russian terms have been derived from German.)

Traditionally, lowmoor deposits or fen types, as they are commonly called in English, are characterized by a high nutrient content (eutrophic), high (over 5) pH values and by vegetation in which the moss cover is characterized by Hypnum (Bryales, brown moss) type mosses rather than sphagna (except eutrophic Sphagnum species). The lowmoor deposits are within the normal groundwater contact and receive nutrients from the adjacent mineral terrain; hence also the term minerotrophic or minerogenic.

Highmoor deposits (raised bogs) are at the other end of the continuum "lowmoor-highmoor". These desposits are characterized by a low nutrient content (oligotrophic), low (less than 5) pH values and sphagnum moss cover in the ground storey. Their only supply of water is atmospheric (rain).

There is a continuum from highmoor to lowmoor with a variety of combinations of the two. These mixed types can be grouped under the name "transitional moors" (German Übergangsmoor).

Typically, the purest raised bogs are formed in the marine climatic zones with a high surplus of water (e.g. Atlantic and Pacific Canada). The purest fens (lowmoor) are often found in areas where the local surplus water is not entirely of atmospheric origin but is due to ground water retained by the topography or the underlying impervious soil types, and commonly in confined areas (e.g. Manitoba, parts of Ontario). The transitional forms are found almost anywhere, but are more common in areas of lower surplus water than required for raised bogs.

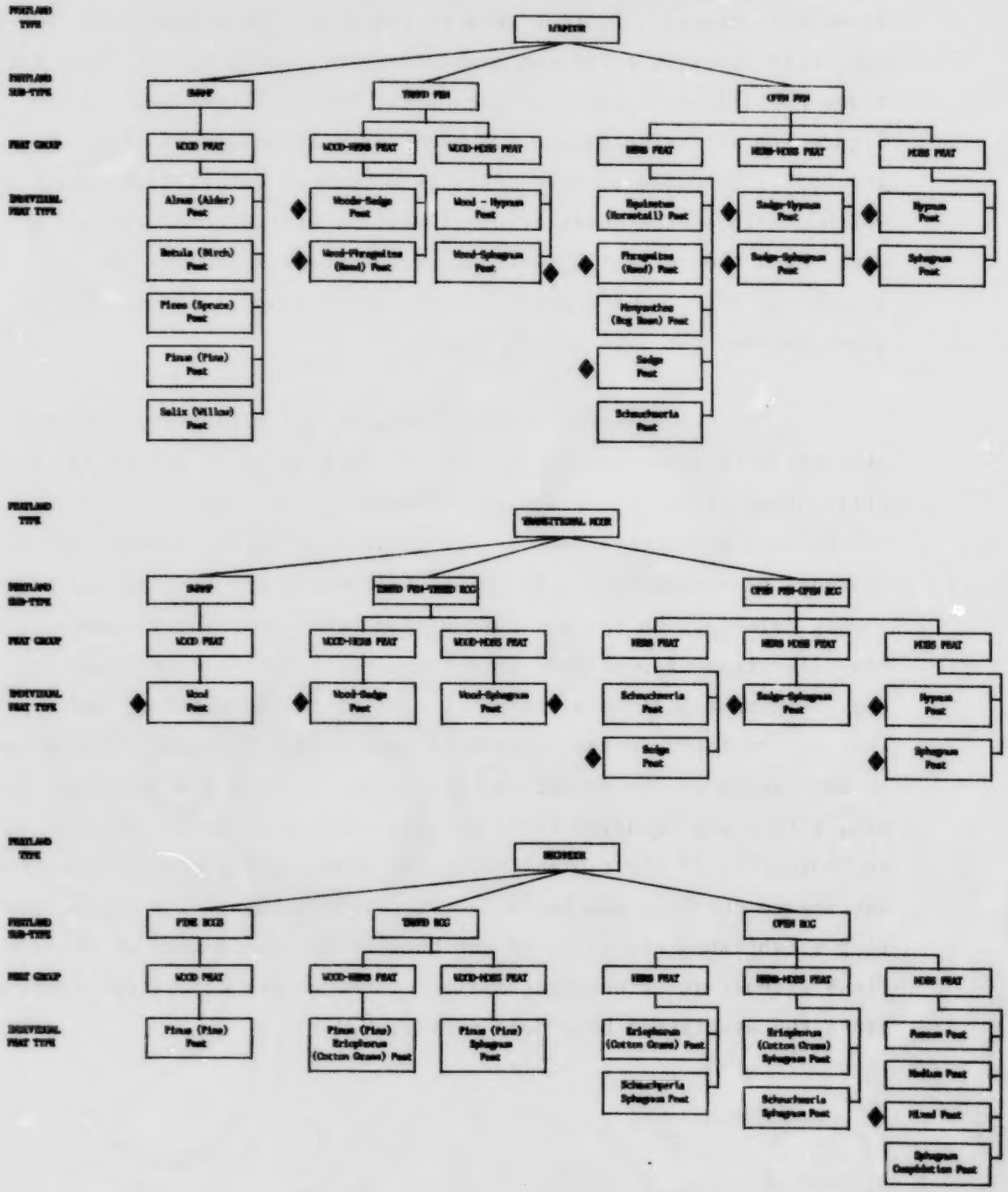
Figure 1-1 is an English translation of the system used in the USSR for peat classification. Figure 1-1 combines the occurrence of the peat types with the deposit type. Due to differences in the recent (10,000-12,000 years) climatic history, vegetation and present day environmental conditions, certain peat types, which are common in the USSR, are uncommon in Canada. Peat types commonly found in North America have been marked with a symbol (◆). Other peat types listed are frequently found in North America, but in such small quantities that they do not have practical significance regarding peat mining statistics or practice. The same peat types can be found in different kinds of deposits. In this case, the difference comes from different species compositions and would not be of significant practical importance. However, the ash content and the degree of humification or decomposition very commonly are different in the peats found in the various peatland types, so that, e.g., in the (highmoor) raised bogs they are generally lower in decomposition and ash content than in the (lowmoors) fens.

Figure 1-1 lists the main peat types individually. In nature, however, large quantities of pure peats composed of one peat type are found only rarely. Thus, e.g., in the lowmoor sub-type treed lowmoors wood peats are listed by species: Alder (Alnus), Birch (Betula) etc. peats. In nature, they are invariably mixed with varying quantities of mosses and sedges.

FIGURE I-1

PEAT CLASSIFICATION SYSTEM USED IN THE U.S.S.R.

RELATIONSHIP BETWEEN THE PEATLAND TYPE AND THE OCCURRENCE OF INDIVIDUAL PEAT TYPES



Source: PEAT ENGINEERS HANDBOOK, 1984

◆ Common also in North America

This mixing of peat types is reflected in Figure 1-2. Figure 1-2 depicts the peatland classification and its relation to generalized peat profiles (rather than to individual peat types) as they are typically found in different peatland types, under the specific conditions prevailing in parts of the USSR. The profiles shown in the Figure are approximate, and are based on a large amount of surveys in the USSR. In Canada, there still is a lack of detailed information which precludes the compilation of similar statistical tables. However, even the currently available information shows that there appears to be some differences in the stratigraphic composition of peats between the USSR and Canada.

The two figures (Figures 1-1 and 1-2) illustrate the basic peat classification system used as the first step in industrial peat utilization planning and design purposes in the USSR to assist in determining parameters such as practical peat yield, optimal solids content, slurry viscosity and other factors in the pumping and pipelining calculations for wet peat mining projects. For instance, the classification of peatlands into the different categories such as, e.g., highmoors, gives a tentative list of the most common peat types that may be found in the deposit (Figure 1-2). This, in turn, gives an indication of the potential uses of the peat in the specific deposit, before any detailed field surveys are carried out. It also gives an indication of the typical ranges of peats in the profile from the surface to the base and tentative viscosity values. The field sampling establishes the range of ash content and the degree of decomposition* without an extensive sampling of the entire deposit(s) required since the statistics have been established.

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* Term "decomposition" is used in the Russian literature and is also used in this report when dealing with the Russian material. It is interchangeable with the term "humification" used in North America.

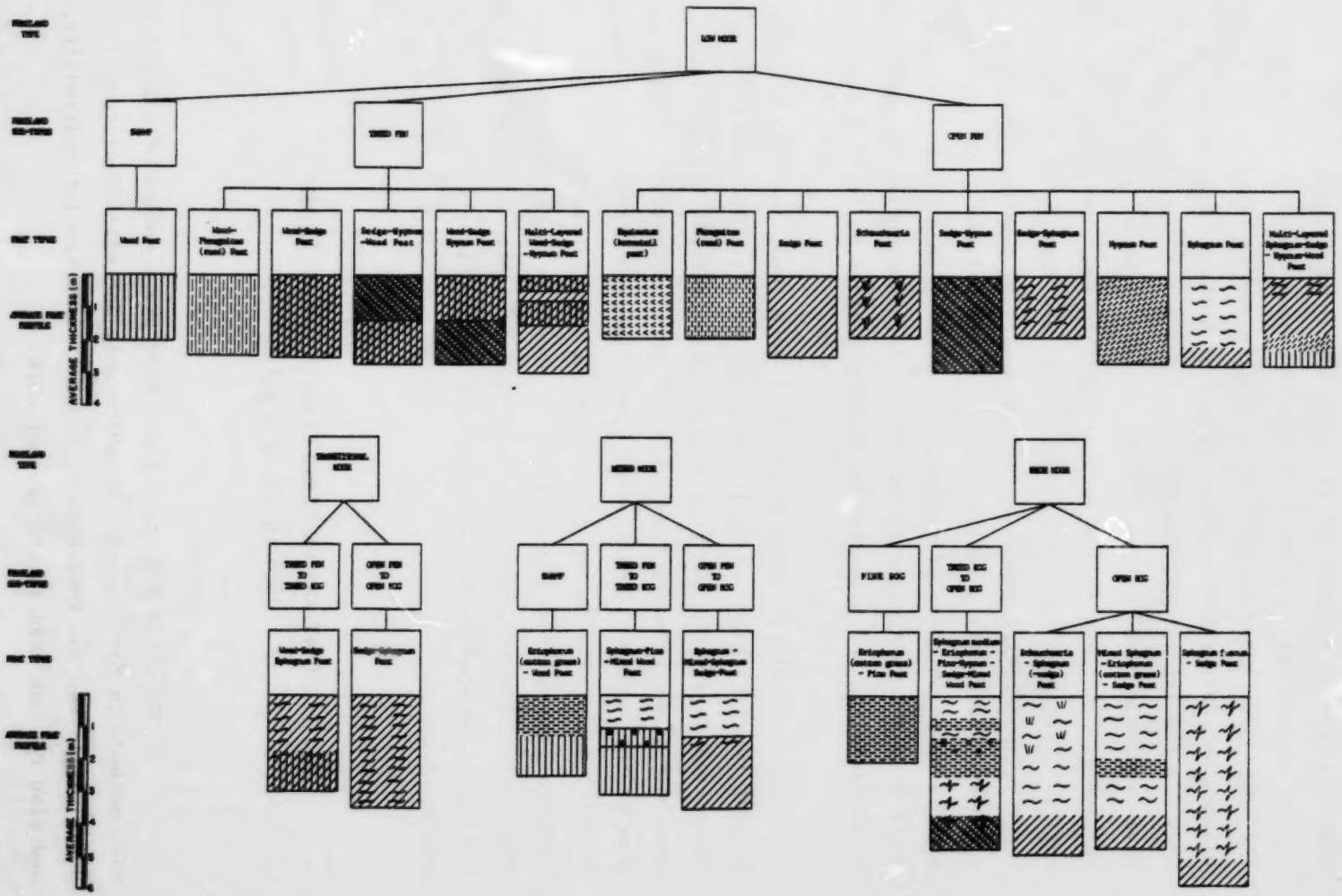


FIGURE 1-2 PEAT CLASSIFICATION SYSTEM USED IN U.S.S.R
RELATIONSHIP BETWEEN PEATLANDS AND THEIR TYPES OF PEAT

The information about the degree of decomposition, ash content, type of deposit and the peat type gives viscosity and the solids content values from the standard curves shown in Figure 1-3. The curves are based on the classification and statistical data established on the peatland and peat types as shown in Figures 1-1 and 1-2. In the laboratory, the viscosity and solids content measurements have been made based on the individual peat types as well as mixed samples at different solids contents, ash content and degree of decomposition levels. In practice, the values are then given as averages for the deposit type based on data from a great number of samples. As a result, the curves shown in Figure 1-3 are derived. The present work is based on these principles and the available Soviet information which is directly applied to the North American conditions supported by the sampling and measuring programs explained in Parts 2 and 3.

In summary, basically in the USSR method, the determination of peat types is based on their botanical origin. The peatlands are classified as a continuum from oligotrophic (raised, highmoor) to eutrophic (fen, lowmoor) types with all the intermediate steps as a part of the series and under the type designation transitional (mesotrophic) moor. The degree of decomposition is determined in the laboratory as described in Part 2. It should be noted that in the USSR system, the more prominent peat type is mentioned first while in the system adopted by the International Peat Society (IPS), it is mentioned last.

1.2 A PEAT AND PEATLAND CLASSIFICATION METHOD USED IN NORTH AMERICA

As the title may imply that there are a number of classification methods in North America of which only one will be discussed here. It is the von Post method, commonly accepted internationally, and also the one used in the present work.

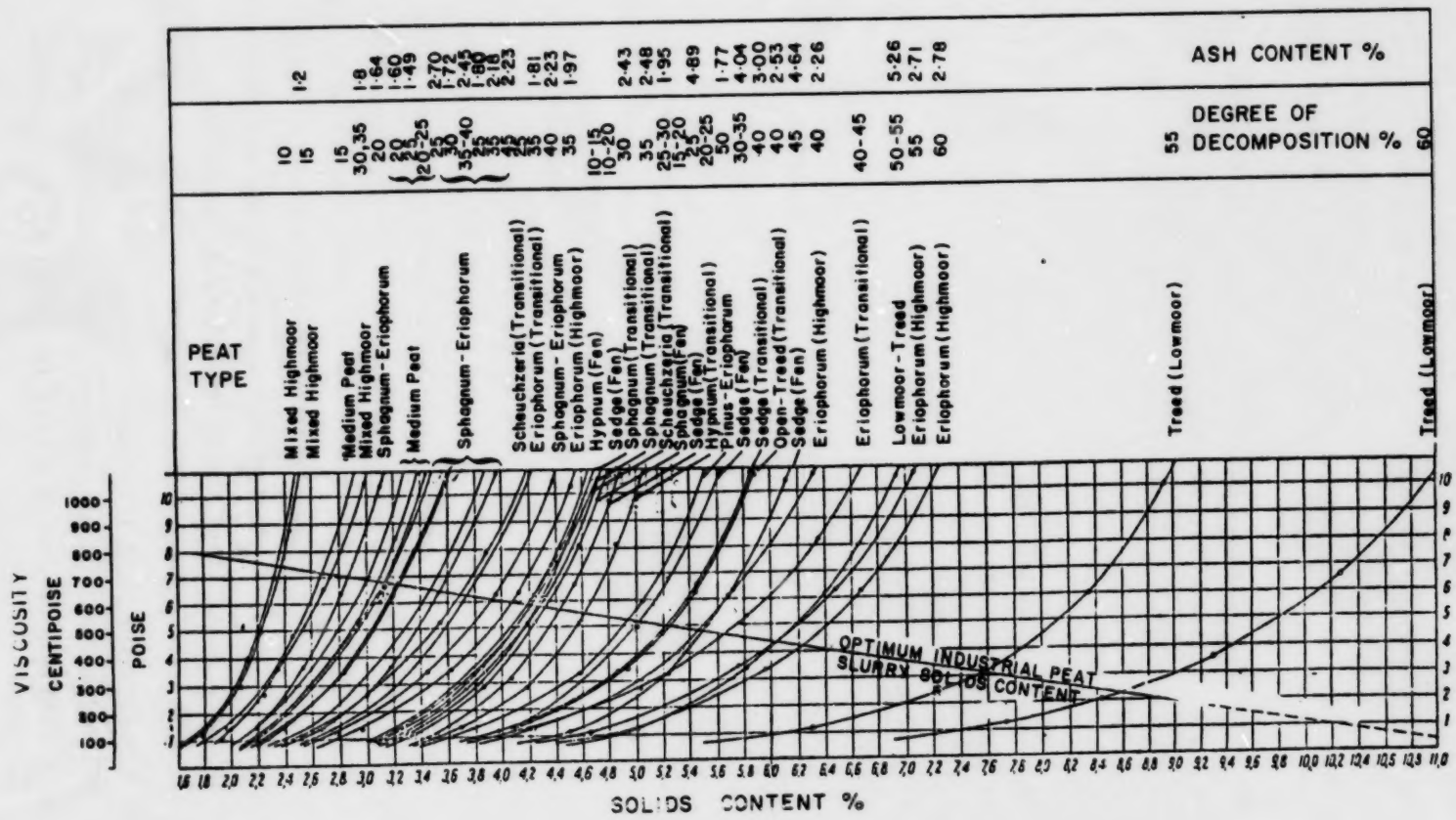


FIGURE I-3 PEAT SLURRY VISCOSITY VERSUS VARIOUS SOLIDS CONTENT FOR DIFFERENT TYPES OF PEAT, DEGREE OF DECOMPOSITION AND ASH CONTENT (ON THE BASIS OF DATA FROM THE U.S.S.R. ONLY)

Source: GORJACHKIN, V.G., 1951

The von Post method was originally designed by Lennart von Post to describe the degree of humification of peat (von Post 1922) as described below in a slightly modified form from the original. It is a field method, and can be supplemented by laboratory methods.

The von Post degree of humification, which is indicated by the letter 'H', is divided into 10 categories described as follows according to Kivinen (1948), Scottish Peat Surveys (1968), and Korpijaakko (1977).

H_1 Completely undecomposed peat.
H_2 Almost completely undecomposed.
H_3 Very slightly decomposed peat.
H_4 Slightly decomposed peat.
H_5 Moderately decomposed peat.
H_6 Moderately strongly decomposed.
H_7 Strongly decomposed peat.
H_8 Very strongly decomposed peat.
H_9 Practically fully decomposed.
H_{10} Completely decomposed peat.

The peat itself is classified according to its botanical origin in a manner similar to that used in the Soviet Union. Thus, in principle, all the peat types mentioned in Figures 1-1, 1-2 and 1-3 can also be found in North America. The differences would be in the species composition since, e.g., the spruce peat in Europe would be composed of Picea abies (Norway spruce) and in North America of Picea mariana (black spruce) remnants. Also the frequencies of occurrence would be different. The peat designation with more than one component (e.g. sedge-sphagnum peat) lists the most prominent type last (contrary to the Soviet system). Also, commonly, a percentage figure is listed to indicate the relative composition. Thus C_4S_6 peat is composed of 40% sedges and 60% of sphagnum. The present day von Post system has been refined and modified from the original and includes

many other factors in addition to the degree of humification. Briefly described in its entirety, the von Post system includes the following in addition to the degree of humification and peat type.

The moisture regime of each peat sample, estimated by utilizing a scale of 1-5 and the symbol 'B' (derived from Swedish blöthet = wetness).

B_1 Dry peat.
B_2 Low moisture content.
B_3 Moderate moisture content.
B_4 High moisture content.
B_5 Very high moisture content.

The fine fiber content, estimated and expressed by utilizing a scale of 0-3 and the symbol 'F'. The fibers are, in this case, mainly derived from Eriophorum (cotton grass). If any other fine fibers are recorded, they should be identified in the peat formula.

F_0 Nil.
F_1 Low content.
F_2 Moderate content.
F_3 High content.

The coarse fibers are also estimated by using a scale of 0-3 and the symbol 'R' in the manner tabulated above. In this case, mainly rootlets are recorded. Often the rootlets of Carex (sedge) are referred to and also identified in the formula as such.

The presence of woody remnants in the peat, which may be a serious problem, especially when peat is mined for moss peat production. For this purpose a scale of 0-3 and the symbol 'W' are used.

W_0 Nil.

W_1 Low content.

W_2 Moderate content.

W_3 High content.

Other information, when pertinent, is added to the end of the formula using suitable symbols and abbreviations. Thus layers of charcoal indicating old fires, seeds and other recognizable plant remnants may be noted.

The last items to be recorded are the possible layers of detritus ooze, gyttja, and finally the type of bottom soil.

When all the information about the site has been recorded, a set of peat formulae for the site will have been obtained. A formula in the set might look something like the following:

Site B400W
Cover FI (Radforth system cf. Table 1-4), open graminoid bog
0-30, CS, H2, $B_3F_0R_2W_0$ (seeds; Pot palustr.).

This indicates that from the surface to the depth of 30 centimeters the peat is composed of Carex-Sphagnum remnants, the degree of humification is H2 (almost completely undecomposed) the quantity of moisture is moderate(B_3), the quantity of fine fibers is nil(F_0) and that of coarse fibers low(R_2), no woody material is present(W_0), and Potentilla palustris (bog bean) seeds were identified.

There are other classification systems widely used in connection with surveys for special purposes such as agriculture, forestry and engineering activities but will not be described here in greater detail. However, it is a simple task to collect additional field information, if needed, in conjunction with the von Post system to

achieve results that might satisfy a larger number of users and also to save time by avoiding successive surveys for future needs.

As far as the peatland classification is concerned the peatlands in North America are classified under the terms fen, bog, swamp and marsh. These types are peatland formation types.

Fens are eutrophic peatlands corresponding quite closely to the lowmoors. Bogs are usually oligotrophic and correspond to highmoors or transitional moors. Swamps are shallow eutrophic deposits and can be found along the edges of bogs and as larger deposits in the fen areas. They correspond sometimes to transitional moors but usually to eutrophic lowmoors as treed (forested) subtypes. Marshes are waterlogged shallow deposits and correspond to various transitional and lowmoor peatland subtypes depending on the type of vegetation (forested, open, brown mosses, sphagna).

All these deposit types can be open or treed. The sub-typing is determined by the vegetation and is expressed as treed, or open sub-formation. Further distinction is based on smaller differences in the vegetation and divides the sub-formations into physiognomic groups such as shrub-rich, tall shrub, low-shrub, dwarf shrub, graminoid, sphagnum bogs and fens; conifer, deciduous and thicket swamps and a number of marsh groups.

This system is used internationally and based on the original classification by Cajander for European conditions (Cajander 1909, 1913). It has been adopted and adapted for Canadian conditions by Jeglum et al (1974). In addition to the ecological peatland classification system, the so-called Radforth (1952) cover (vegetation cover) class system designed for engineering applications has been commonly used in Canada. Table 1-1 describes this system briefly. It utilizes a three letter combination to describe the vegetation type. Cover is assigned a letter only if it is 25% or more of the total. Thus, e.g.,

BEI refers to a deposit composed of at least 25% of each: "B" refers to trees 1-4.5 m high, "E" to shrubs up to 0.5 m high and "I" to moss cover up to 10 cm high. The advantages of this system is that it does not require specialized botanical knowledge and allows a simple description of the vegetation in a format which enables a preliminary practical assessment of the technical problems that might be encountered in taking a specific deposit into use.

There are a number of other classification systems for peat in addition to the ones described above. Most of them are designed for a specific purpose and usually have a limited use otherwise. One that has gained considerable acceptance among North American soil scientists is the one proposed by Day in 1968 (Day 1968). It divides the deposit into tiers (surface, middle, bottom) each of which may have one or more types of layers: fibric mesic, humic and other layers (e.g. typic, fennic, terric, etc.). These combine to describe peat as fenno-fibrisol, humic-mesisol etc. The drawback of this system is that it does not address the botanical origin of peat and thus ignores the basic characteristics of peat. In other words, e.g., fenno-fibrisol encompasses a number of peats of different origin botanically and thus combines peat types with different ash contents, pH values and viscosities depending on the type of deposit it originates in. It could be a combination of, e.g., sedge-shrub peat or sphagnum-sedge peat which both have a different set of characteristics significant in viscosity and solids contents determinations.

The aforementioned kinds of problems exclude non-botanical classification systems from being utilized in wet peat mining calculations as being too generalized for determining optimum solids contents for peat slurry pumping.

1.3 COMPARISON OF NORTH AMERICAN AND USSR PEAT TYPE CLASSIFICATION SYSTEMS

131 PEAT TYPES

The previous chapters have described the peat classification systems used in Canada and in the USSR. In the following, a concise comparison of the systems is given. The previous description indicates that basically the two systems are very similar as they both are based on the determination of the peat types according to their botanical origin. However, there are differences in the peat types in these two regions depending on a number of factors explained below.

Similarities in naming the peat types in the USSR and Canada are apparent. The most common basic peat components are sphagnum, sedges, and a number of individual plant groups such as Eriophorum (cotton grass), Equisetum (horsetail), Phragmites (reed), Menyanthes (bog beam) and Scheuchzeria. All appear as common peat types in Figures 1-1 and 1-2, used in planning wet peat mining operations in the USSR. Figure 1-1 lists the main peatland types, subtypes and under each subtype the most common peat types found in the USSR. In the USSR, peat and peatland research has a long history and a large quantity of data has been compiled on its various aspects. In Canada, very little statistical information concerning peat and peatlands exists and thus some of the peat types listed in Figure 1-1 presently have to be listed as rare or non-existent in Canada. The types commonly found in Canada have been marked with a symbol (◆). The names of peat types in Figure 1-1 are the same as those used in Canada, even when translated literally from Russian. The Russian practice is to refer also to the type of deposit the peat comes from, e.g., highmoor Eriophorum peat, lowmoor Equisetum peat, etc. In Canada, the deposit type is not mentioned, the significance of this practice will be discussed later.

Figure 1-2 lists the groups of peat under the various peatland types. Usually peats are not pure and are a mixture of a number of plant species. The nomenclature in Figure 1-2 is the same as in Canada. The only difference is the use of the term "multi-layered". This refers to a layered arrangement of different peat types in the deposit and may reflect specific conditions prevailing in some parts of the USSR. In general, there is always some layering present in the peat deposit, but the layers are intermittent and as a unit the entire deposit cannot be called multi-layered - rather it would be called mixed - a term used also in the Russian literature (Figure 1-2).

A practical and visual difference in the USSR and Canadian systems is the order in which the components of the peat are listed. In the Canadian system, the components are listed in an increasing order of importance, e.g., sphagnum-sedge peat refers to a peat where sedge predominates. This follows the internationally accepted standard also used by soil scientists (e.g. sandy clay = predominantly clay with some sand). The USSR system lists the most important component first, e.g., sedge-sphagnum peat (sedge predominant).

The similar or identical names of peat types do not necessarily mean that the peats with the same name in the USSR and Canada are the same. There are differences that arise from the peat being composed of the same group of plants (e.g. Carex) but of different species (e.g. Carex aquatilis or Carex rostrata) with different physical and chemical characteristics resulting in peats differing from each other.

Secondly, there have been differences in the environmental conditions (climatic, edaphic, hydrological, microtopographical) during the developmental history of deposits. Paludification commenced about 10,000 - 12,000 years ago, soon after de-glaciation, and is still continuing. This period has undergone a number of stages or phases with markedly variable climatic conditions. Each phase had its

own characteristic vegetation. As a result, peatlands under paludification have developed through different stages and are composed of the remnants of the prevailing vegetation of each phase. Thus, they display different proportions of various peat types on the two continents as a reflection of their past development. Thus, the frequency of occurrence of, e.g., highmoor sphagnum peat in the USSR may be quite different from that in Canada in that it may alternate in different proportions with other peat types and be composed of different plant species.

Figure 1-2 depicts the average thickness of peat in general and that of various peat types in the peatland types and sub-types in the USSR. It also gives average ("typical") peat profiles for each subtype showing the sequence and combination of individual peat types forming the profiles. Information of this kind is yet lacking in Canada due to the fact that very little detailed peatland surveys have been carried out. However, the existing, though scanty, information in Canada indicates that the average ("typical") peat profiles would be different from those shown in Figure 1-2, due to the differences in the frequency of occurrence of peat types.

132 PEATLAND TYPES

As the previous description indicated, the peatland classification system used in the USSR and in Canada, where the von Post has been recently adopted, are based on the same original design (Cajander 1909, 1913). The apparent differences stem mainly from the different usage of the terms. In the USSR system, the division into lowmoor, transitional moor and highmoor terms are retained while in North America the terms have assumed a geomorphological connotation and a more ecological terminology has been adopted. Table 1-2 gives the equivalent terms for the Russian and English language. The Russian term peatland type corresponds to the English term formation and the Russian term peatland subtype to the English physiognomic group. The

TABLE 1-1

Summary of Properties Designating Nine Pure Radforth Coverage Classes*

Coverage Type (Class)	Woodiness vs. Non-woodiness	Stature (approx. height)	Texture (where required)	Growth Habit	Example
A	woody	15 ft. or over (4.5 m)	-	tree form	Spruce, Larch
B	woody	5 to 15 ft. (1.5 m to 4.5 m)	-	young or dwarfed tree or bush	Willow, Birch, Spruce, Larch
C	non-woody	2 to 5 ft. (0.5 m to 1.5 m)	-	tall grass-like	Grasses
D	woody	2 to 5 ft. (0.5 m to 1.5 m)	-	tall shrub or very dwarfed tree	Willow, Birch, Labrador tea
E	woody	0 to 2 ft. (0 to 0.5 m)	-	low shrub	Blueberry Laurel
F	non-woody	0 to 2 ft. (0 to 0.5 m)	-	mats, clump or patches sometimes touching	Sedges, Grasses
G	non-woody	0 to 2 ft. (0 to 0.5 m)	-	singly or loose association	Orchid Pitcher, Plant
H	non-woody	0 to 4 in. (0 to 10 cm)	leathery to crisp	mostly continuous mats	Lichens
I	non-woody	0 to 4 in. (0 to 10 cm)	soft or velvety	often continuous mats sometimes in hummocks	Mosses

* From Radforth, 1952.

TABLE 1-2
Classification Terminology

		SOVIET TERMS	NORTH AMERICAN TERMS
Russian: English:	Peatland Type Formation	Lowmoor	Fens, swamps and marshes (formations), eutrophic peatland, minerogenic peatland.
Russian: English:	Peatland Subtype Physiognomic Groups	Swamp	Swamps, eg. conifer swamp (physiognomic groups).
		Treed Fen	Various fen types such as treed shrub fen, treed graminoid fen.
		Open Fen	Various fen types such as open graminoid fen etc.
Russian: English:	Peatland Type Formation	Transitional Moor	Formations between eutrophic (fens swamps, marshes) and oligotrophic (bog) types; mesotrophic peatlands.
Russian: English:	Peatland Sub-Type Physiognomic Groups	Treed/Fen to Treed Bog	Physiognomic groups such as treed lowshrub fen-bogs, etc.
		Open Fen to Open Bog	Physiognomic groups between these two such as open lowshrub fen-bog.
Russian: English:	Peatland Type Formation	Mixed Moors	These are formations closer to either end of the continuum and may show either fen or bog characteristics e.g. open graminoid fen, with some sphagna to indicate slightly boggy conditions.
Russian: English:	Peatland Type Physiognomic Groups	Highmoor	Bogs includes raised bogs as the main type. Also other types showing oligotrophic conditions. Often the mixed moors and transitional moors are included in this group.
Russian: English:	Highmoor Peatland Subtypes	Treed	Treed physiognomic groups such as treed sphagnum bog (ombrogenic), treed low shrub bog etc.
		Open	Open physiognomic groups such as open graminoid bog.

same Russian term lowmoor, highmoor and transitional moor in English usage have become in some cases to mean morphological types such as flat bog, raised bog etc. and are not applicable to the present study.

The main difference between the USSR and Canadian usage is that in the Russian system a tight association is made between the peatland type and the peat type. Thus, as was mentioned earlier, in the USSR system, peat type and peatland type are mentioned together, e.g. lowmoor sedge peat. For Canadian peat, we may be speaking of, e.g., sedge peat, without any reference to the formation (or peatland type). It appears that the USSR system maintains that sedge peat in different peatland types is different while the Canadian system implies that this is not necessarily the case. However, it is possible that both concepts are correct depending on the details of definition.

Peatlands have not always been the same. What today appears as a highmoor or an open bog may have gone through a number of stages in the past which all have had their own peat types as a function of ecological conditions. Each of the stages may have appeared as a different bog type, so that a raised bog (highmoor) may once have been a lowmoor or fen. In fact, research has established that due to general climatic changes, as well as changes in both hydrological and edaphic conditions originally prevailing at the site of paludification and caused by the paludification itself, a European raised bog has typically gone through a simplifed set of phases as follows: paludification starts as primary paludification of forestland; the first type is often a eutrophic swamp with wood peats predominant. As the process goes on and the peat layer thickens, the centre starts displaying characteristics of an open, eutrophic fen with sedge and sedge sphagnum peat predominant. The edges at the same time encroach outwards into the adjacent forestland forming a zone of swamps. Once the peat thickness has reached a few meters, the centre will be cut from contact with the groundwater and the deposit will become

ombrogenic (highmoor) in the centre. The sphagnum peats will become predominant. Around the central dome, a zone of low shrub type is common with shrub-sphagnum peats. This in turn is surrounded by swamps. By drilling through the centre of the deposit one could find, representatives of each phase; layers of varying peat types with sphagnum peat on surface, shrub and sphagnum peat, sedge and sedge-sphagnum at the greater depth and, finally, wood peat at the bottom. This is a simplified sequence and in nature usually is more complex and also influenced by the local edaphic and hydrological conditions and shows a great number of permutations.

In the USSR, large numbers of deposits have been surveyed in detail so that it has been possible to calculate a set of averages as indicated in Figure 1-2. However, as the example above shows, sedge peat taken from a raised bog may represent sedge peat at an earlier fen phase and thus, e.g., lowmoor sedge peat may not be much different from highmoor sedge peat as they both were formed in similar fen conditions. These are considerations that will have to be studied in North America in order to arrive at statistics that correspond to those used in the USSR.

133 APPLICATION OF THE USSR AND NORTH AMERICAN SYSTEMS

In determining the parameters for slurry pumping, the USSR system of peat and peatland classification, as well as the USSR laboratory and calculation methods are used in the present study. In the USSR, a large number of peatlands have been studied in detail and very extensive sampling programs have been performed on both individual peat types as well as on peatland types. In order to design peat slurry pumping systems (hydropeat) for industrial purposes in a manner that is technically and economically feasible, the optimum solids contents has to be calculated. This can be done in either of two ways. The first is to carry out an extensive and expensive detailed

sampling and laboratory analysis for each deposit on which to base the calculations or, to develop a system whereby the easily measured characteristics, such as the peatland type, peat type and ash content and the degree of humification (decomposition) only have to be recorded to obtain the optimum slurry pumping solids concentration for the deposit. The latter is used in the USSR practice.

In order to develop a statistical system for the calculation of optimum solids content, researchers in the USSR have adopted the peat and peatland type classification shown in Figure 1-1. In addition, they have collected sufficient data to produce a statistical average peat thickness and peat type profile system, shown in Figure 1-2, and to relate it to peatland types. After this was done the next step was to determine the viscosity limits for each peat and peatland type, based on a knowledge of the average peat type distribution under each peatland type. To do this, a large number of viscosity measurements on selected pure and combined peat types such as Sphagnum fuscum peat (pure type), and sphagnum-sedge peat (combined type) were done at different degrees of decomposition, ash content and solids content. These measurements have given viscosity limits to the pure peats at different degrees of decomposition and solids contents and also have given correction factors to account for the ash content.

In order to have a broad statistical basis for the determination of the viscosity of various peat types at varying degrees of decomposition and ash contents, the average degree of decomposition and ash content limits for these peat types correlated to the peatland types that were encountered, were determined. Combining these data with the known average frequency of occurrence of peat types in the main peatland types, the overall statistics for the determination of the viscosity was obtained and allowed compilation of tables and graphs on the viscosity of peat for known peat types to aid in viscosity determination without the requirement for extensive laboratory analysis and sampling for each location.

In order to measure the viscosity, the degree of decomposition has to be measured. This is done in the USSR in the laboratory according to the method explained in Part 3. The degree of decomposition and ash content are measured on all the samples for which the viscosity is performed. The final results of all the measurements have been compiled in graphs and tables. Figure 1-3 shows a graph of the solids content that peat slurries attain at different viscosity levels (which are dependent on degree of decomposition and ash content) and also, the optimum solids content for industrial pumping and pipelining purposes for specific peat types and also for specific peatland types(2). For the latter, the calculations are based on the average conditions as shown in Figure 1-2. Finally, if one knows either the type of peatland or peat, one can estimate the optimal solids content for preliminary planning without elaborate field or sampling work.

The preliminary work carried out for this study indicates that the North American peats and peatland types have the same characteristics as do the Russian. In fact, a few laboratory tests on North American samples reveal that the North American peat and peatland types fit quite well into the Russian system. Therefore, it has been deduced that the correlation of the North American peat and peatland types with the Russian is positive, and as well, that the characteristics of the similar peat types are close. However, due to the lack of a sufficient statistical background, the positive results given later in Part 3 must still be regarded as preliminary and will have to be confirmed by a larger sample population and practical pumping tests. Also, an attempt is made to compare the von Post degree of humification and the USSR laboratory degree of decomposition values in order to be able to use available North American peatland inventory results. Presently it appears that, depending on the peat type, the correlation shows variations. This may be due to insufficient data.

TABLE 1-3

Summary of Analytical Results from Canadian and New York State Peat Samples

Peatland	Type of Peat	Sample No.	Approx. Depth of Sampled Layers (m)	Moisture Content %	Ash Content (Dry Basis) %	pH	Average Laboratory Degree of Decomposition %	von Post Degree of Humification Scale (H)
Parry Sound (Ontario)	sedge-sphagnum	1	0.6 - 1.2	88.0	6.1	3.7	16.2	H6
Parry Sound (Ontario)	sphagnum-sedge	2	1.2 - 1.6	89.9	13.4	4.0	17.8	H7
Parry Sound (Ontario)	sedge-sphagnum	3	1.6 - 1.9	90.2	41.3	4.5	18.2	H8
Folley Bog No. 2 (NYS)	wood-sedge & sedge-sphagnum	1	0 - 3.2	92.9	1.7	3.8	19.8	H5-H6
Folley Bog No. 1 (NYS)	wood-sedge & sedge-sphagnum	2	0 - 3.2	92.1	2.7	3.8	20.4	H5-H6
Fort Drum (NYS)	wood-sedge & sedge-sphagnum	6	0 - 3.5	89.2	15.7	6.3	22.3	H7-H8
Bog JJ4-2 (NYS)	sedge-sphagnum	7	0 - 3.0	89.5	14.3	6.4	22.2	H6-H7
Inkerman Ferry (N.B.)	sphagnum-medium	1	2.0	91.1	1.0	3.4	9.25	H4
Inkerman Ferry (N.B.)	sphagnum-medium	3	0 - 1.0	89.1	0.6	3.4	10.5	H4
Inkerman Ferry (N.B.)	sphagnum (mixed)	4	1.0 - 3.5	92.5	1.1	3.7	11.5	H4
Inkerman Ferry (N.B.)	sphagnum (mixed)	5	3.5 - 4.5	91.4	3.0	3.7	11.0	H5-H6
Inkerman Ferry (N.B.)	sphagnum (mixed)	6	4.5 - 5.5	91.4	3.0	3.9	14.0	H7
Deschambault Lake (Sask.)	sedge-sphagnum	1	0.5 - 1.5	91.6	7.2	5.8	12.5	H3-H4
Deschambault Lake (Sask.)	sedge-sphagnum	2	1.0 - 1.5	90.7	6.5	6.0	12.25	H5
Deschambault Lake (Sask.)	sedge-sphagnum	3	1.5 - 2.0	91.0	7.0	6.2	13.75	H4-H5

TABLE 1-4

Results of the Microscopic Analysis of
Canadian and New York State Peat Samples

Sample	Depth Sampled (m)	Amorphous Granular (%)	Cyperaceae (%)	Sphagnum (%)	Other Mosses (%)	Ericacae (%)	Lignin (%)
Parry Sound, Sample 1	0.6-1.2	44	43	1	10	2	0
Parry Sound, Sample 2	1.2-1.6	64	27	0	7	2	0
Parry Sound, Sample 3	1.6-1.9	80	18	0	1	1	0
Folley Bog, Sample 1	0-3.2	41	3	41	0	15	0
Folley Bog, Sample 2	0-3.2	48	0	43	0	9	0
Fort Drum, Sample 6	0-3.5	57	3	25	0	13	2
Bog JJ4-2, Sample 7	0-3.0	45	1	33	0	17	4
Inkerman Ferry, Sample 1	0-2.0	10	7	75	0	5	3
Inkerman Ferry, Sample 3	0-1.0	13	2	66	0	13	6
Inkerman Ferry, Sample 4	1-3.5	11	5	78	0	4	2
Inkerman Ferry, Sample 5	3.5-4.5	14	14	63	0	7	2
Inkerman Ferry, Sample 6	4.5-5.5	24	10	57	0	9	0
Deschambault Lake, Sample 1	0.5-1.0	29	43	6	0	17	5
Deschambault Lake, Sample 2	1.0-1.5	22	64	2	0	5	7
Deschambault Lake, Sample 3	1.5-2.0	40	40	14	0	4	2

PART 2

LABORATORY METHOD FOR THE DETERMINATION OF DEGREE OF DECOMPOSITION

2.1 INTRODUCTION

Degree of decomposition (humification) is the most important parameter required for the calculation of optimum solids content for the pumping of peat slurries. Knowledge of the degree of decomposition is needed to accurately predict the actual yield of solids obtained from one cubic meter of in-situ peat, expressed as tonnes of dry matter. The degree of decomposition is also a function of parameters such as humic acid, bitumen, and carbon content and heat of combustion and thus a rough indicator of their values. Degree of decomposition can be expressed as a percentage of amorphous mass of peat (humus) of the total mass of peat.

There are several methods for determining the degree of decomposition:

a) Macroscopic or visual methods: One method commonly used is the von Post degree of humification (H1-H10). Another system, used mostly in the USSR for inventory field work, expresses the degree of decomposition as a percentage.

b) Microscopic method: It is based on the microscopic analysis of the degree of decomposition.

c) The Centrifuge method: The centrifuge method has been used since 1972 in the USSR, as a GOST standard, and is the main method for determination of the degree of decomposition (or humification). The centrifuge method, due to its objective nature, is easily repeated by trained laboratory personnel. The procedure is outlined in some detail in the following sections.

d) Pjavtshenko's Method: This method was popular in the 1960's in the USSR and was based on the interdependence of degree of decomposition and the volume weight of dry, ash-free peat. The method is not included in recent Russian publications.

2.2 DESCRIPTION OF LABORATORY METHOD FOR DEGREE OF DECOMPOSITION TEST

221 INTRODUCTION

In the USSR, for many decades, a laboratory method was used for determining degree of decomposition (with the results expressed as a percent) when the "hydropeat" technology for wet peat mining was used. The centrifuge method is considered to obtain the same degree of decomposition values for the respective peats as with the method previously employed.

The following is a description of the apparatus and methods used to determine the degree of decomposition of peat by the centrifuge method. Both the apparatus used and procedure followed met all the requirements for the test as described in the USSR Standard, GOST 10650-72 (3) (Appendix A).

Using the previous USSR information available to Monenco, and the facilities of the Ontario Research Foundation, the following steps were carried out in the current work related to the laboratory degree of decomposition testing of the various peat samples:

- the centrifuge method, corresponding test procedures and calculating method was described;

- all the necesary laboratory apparatus was selected and/or fabricated;

- a number of samples of Canadian and U.S. peat types with different degrees of decomposition were selected (H3 to H8). The degree of decomposition tests were carried out on the selected samples; and

- a concurrent von Post determination was also carried out on the samples and the results were compared to the laboratory tests.

222 EQUIPMENT AND MATERIALS

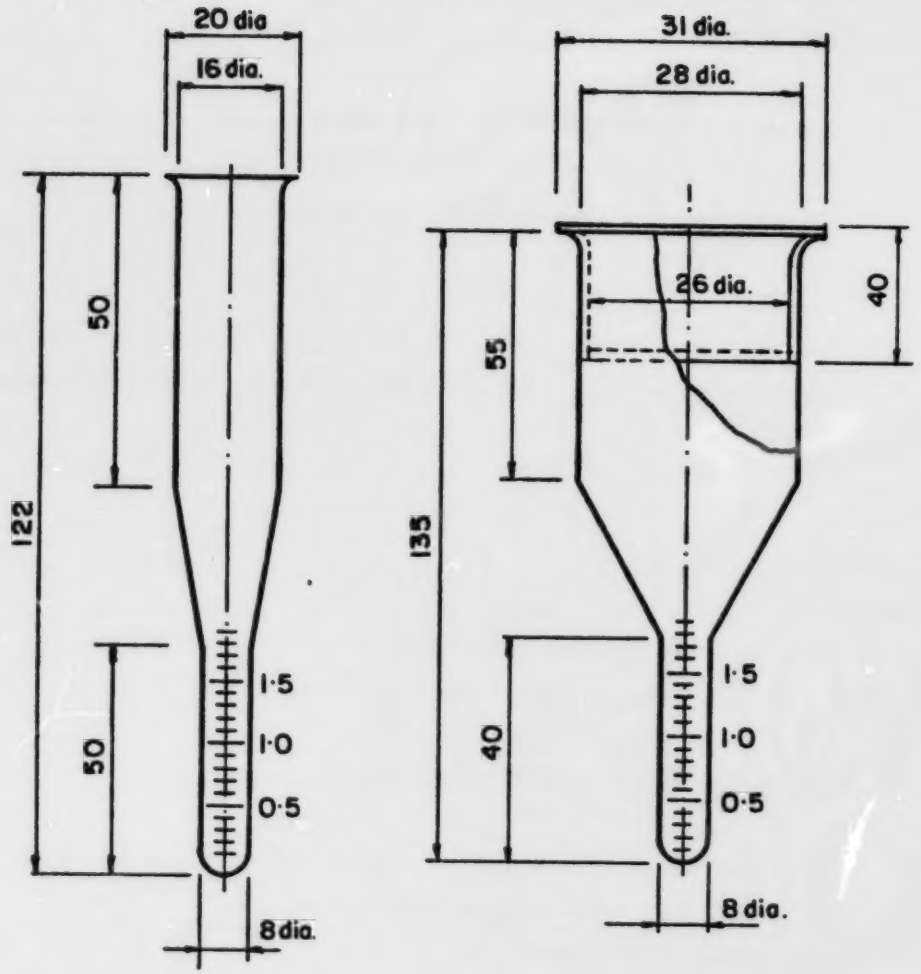
To carry out the determination in the laboratory, the following equipment and materials are required:

- about 200 grams of well mixed peat;

- four small centrifuge tubes of about 10 mL total capacity with bottom graduations between 0 and 2 mL in 0.1 mL increments (see Figure 2-1);

- four large centrifuge tubes of about 36 mL total capacity with bottom graduations between 0 and 2 mL in 0.1 mL increments. These tubes were fabricated specifically for the project, as satisfactory tubes were not available commercially;

- four 0.25 mm mesh screen sieves fitted into the top of the large centrifuges with about 11 mL capacity of peat in the container above. These were also fabricated specially for the project using brass tubing and stainless steel mesh;



All dimensions shown in mm .

FIGURE 2-1 CENTRIFUGE TUBES AND SIEVE DIMENSIONS.

Source: USSR GOST 10650-72

- 10% ferric chloride solution;

- small sampling tube; and

- two laboratory centrifuges: a Heraeus Christ centrifuge was used for the large tubes and an IEC centrifuge for the small tubes.

223 PROCEDURE

The laboratory procedure basically consists of centrifuging the raw peat sample to obtain a reading of the total apparent volume of sample, followed by a 0.25 mm sieve separation (the oversize material being the unhumified fibers, parts of plants and roots) and centrifuging of the undersize (humified part) to obtain the apparent volume of the humified portion. A nomograph was developed in the USSR to read the percentage degree of decomposition directly, based on the volumetric readings obtained from the two centrifugings. This method is used for peat with a moisture content greater than 65%. The method is only applicable to virgin peat and not "processed" peat. The following describes the various steps in the procedure (see also Appendix A):

a) The raw peat is pressed down on a flat surface to a thickness of 3 to 4 mm. Where sample volume permits, an area of 35 x 25 cm of sample is used. A total of about 200 grams of peat is required.

b) The pressed-out sample is pierced in several places with a hollow metal sampling tube so that a representative sample of about 0.3 to 0.5 g is obtained.

c) The sample is removed from the sampling tube and placed in a small centrifuge tube.

d) The tube is filled with distilled water and the peat solids are dispersed using a glass rod.

e) Two to three drops of 10% ferric chloride solution are added to the centrifuge tube and mixed gently.

f) Steps "b" to "e" are repeated for four samples.

g) The four centrifuge tubes are placed in the centrifuge and spun for 2 minutes at 1000 RPM.

h) The centrifuge tubes are removed and the volume of solids at the bottom of each tube recorded. If the interface is uneven, the average between the highest and lowest points is taken.

i) The solids in each of the small centrifuge tubes are gently mixed and transferred into four separate large centrifuge tubes with 0.25 mm mesh sieves placed in the tops. The small tubes are rinsed out with distilled water ensuring that all the solids are transferred to the large tubes.

j) The four large centrifuge tubes are placed in the centrifuge and spun at 1000 RPM for 2 minutes.

k) The tubes are removed and the volume of solids in the bottom of each tube is recorded.

224 METHOD OF CALCULATION OF DEGREE OF DECOMPOSITION

For each sample, the volume of solids separated in the small tube and the volume of solids from the large tube are used to determine the degree of decomposition from the nomograph as shown in Figure 2-2. Based on the botanical origin of the sample, the percent decomposition is read from the appropriate scale.

225 STANDARDIZATION OF RESULTS

According to the USSR standard, for raw peat with a moisture content above 65%, the following accuracies can be obtained after averaging the results from four samples:

Degree of Decomposition (%)	Accuracy (%)
1 - 15	±1.5
15 - 30	±2.0
30 - 50	±3.0
greater than 50	±5.0

The maximum allowable difference between four individual samples is (moisture above 65%):

Degree of Decomposition (%)	Permissible Difference (%)
1 - 15	4
15 - 30	6
30 - 50	9
greater than 50	15

Even with many repeats, it was not always possible during the course of the ORF testing to achieve results within the above limits.

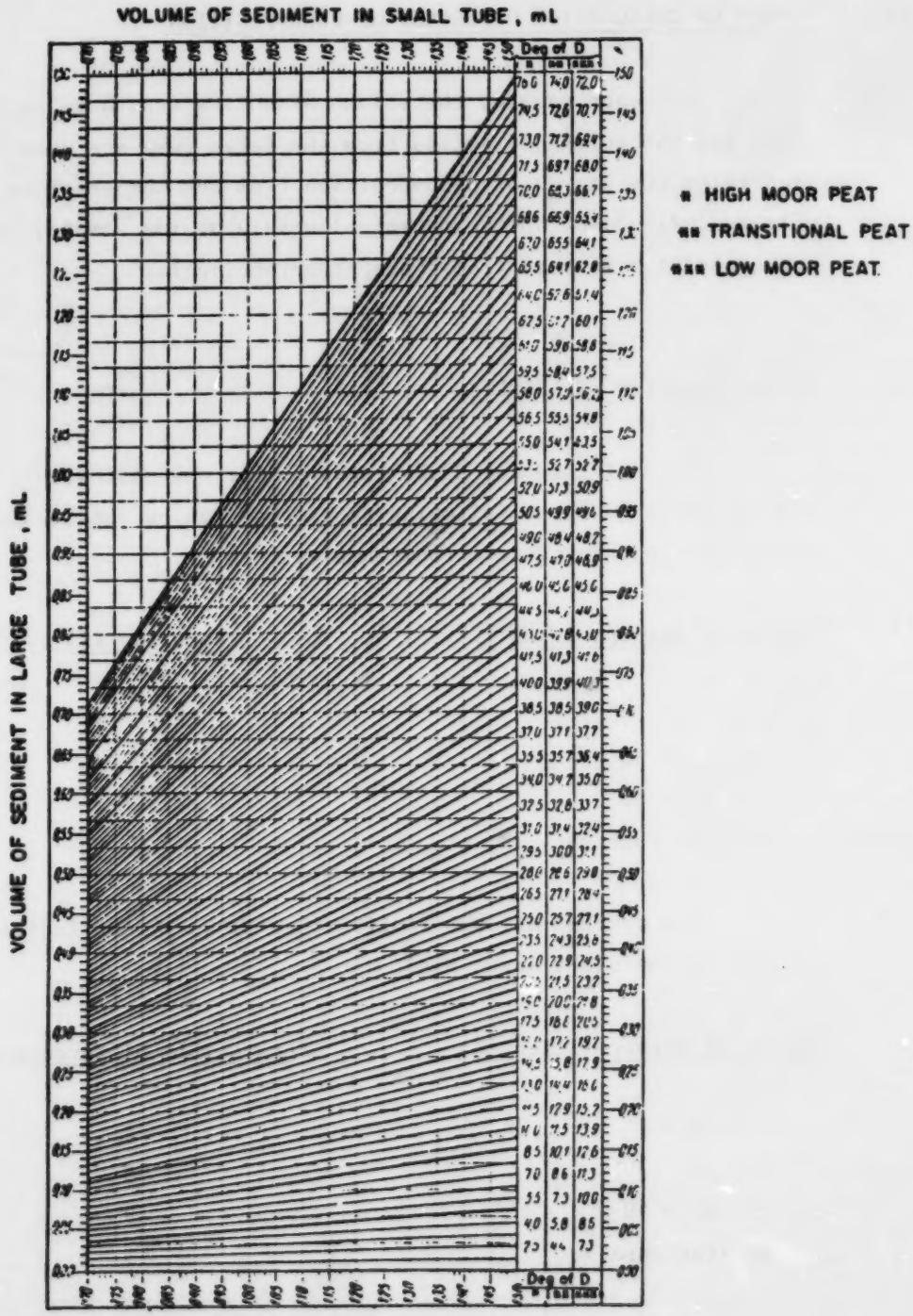

VOLUME OF SEDIMENT IN SMALL TUBE, mL
VOLUME OF SEDIMENT IN LARGE TUBE, mL
Deg of D
Deg of D
I HIGH MOOR PEAT
II TRANSITIONAL PEAT
III LOW MOOR PEAT

FIGURE 2-2 DEGREE OF DECOMPOSITION CONVERSION CHART

Source: USSR GOST 10650-72

If the ash content of the peat is greater than 15%, then the results are adjusted as recommended by the original standard (Appendix A) by decreasing the percentage decomposition by the following amounts:

Ash Content (%)	Correction (%)
15 - 25	2
25 - 35	3
35 - 45	4
45 - 55	5

2.3 DEGREE OF DECOMPOSITION OF VARIOUS CANADIAN AND NEW YORK PEATS

The test results for the samples and sub-samples collected are given in Appendix B. Table 2-1 summarizes the data. Values of degree of decomposition obtained during the tests ranged from a low of 9.25% (New Brunswick) to a high of 22.3% (New York) for top to bottom peat samples. It should be noted in Appendix B that some of the uncorrected (or unadjusted) degree of decomposition values of Parry Sound sub-samples are higher and exceed some of the New York sub-samples. However, the Parry Sound samples were much higher in ash content, giving lower corrected (adjusted) degree of decomposition results.

In the field, it is often difficult to determine the degree of humification accurately when the ash content of the sample is high; this is shown particularly in the case of the Parry Sound samples where the field test gave consistently higher levels of humification than the laboratory tests - when adjusted to account for the high ash values. Selection of the various sampling sites were initially made

TABLE 2-1
Comparison of Results of Laboratory Degree of Decomposition and von Post Humification Tests

Peatland	Type of Peat	Sample No.	Approx. Depth of Sampled Layers (m)	Ash Content (Dry Basis) %	pH	Average Laboratory Degree of Decomposition %	von Post Degree of Humification (H)
Parry Sound (Ontario)	sedge-sphagnum	1	0.6 - 1.2	6.1	3.7	16.2	H6
Parry Sound (Ontario)	sphagnum-sedge	2	1.2 - 1.6	13.4	4.0	17.8	H7
Parry Sound (Ontario)	sedge-sphagnum	3	1.6 - 1.9	41.3	4.5	18.2	H8
Folley Bog No. 2 (NYS)	wood-sedge & sedge-sphagnum	1	0 - 3.2	1.7	3.8	19.8	H5-H6
Folley Bog No. 1 (NYS)	wood-sedge & sedge-sphagnum	2	0 - 3.2	2.7	3.8	20.4	H5-H6
Fort Drum (NYS)	wood-sedge & sedge-sphagnum	6	0 - 3.5	15.7	6.3	22.3	H7-H8
Bog JJ4-2 (NYS)	sedge-sphagnum	7	0 - 3.0	14.3	6.4	22.2	H6-H7
Inkerman Ferry (N.B.)	sphagnum medium	1	2.0	1.0	3.4	9.25	H4
Inkerman Ferry (N.B.)	sphagnum medium	3	0 - 1.0	0.6	3.4	10.5	H4
Inkerman Ferry (N.B.)	sphagnum (mixed)	4	1.0 - 3.5	1.1	3.7	11.5	H4
Inkerman Ferry (N.B.)	sphagnum (mixed)	5	3.5 - 4.5	3.0	3.7	11.0	H5-H6
Inkerman Ferry (N.B.)	sphagnum (mixed)	6	4.5 - 5.5	3.0	3.9	14.0	H7
Deschambault Lake (Sask.)	sedge-sphagnum	1	0.5 - 1.5	7.2	5.8	12.5	H3-H4
Deschambault Lake (Sask.)	sedge-sphagnum	2	1.0 - 1.5	6.5	6.0	12.25	H5
Deschambault Lake (Sask.)	sedge-sphagnum	3	1.5 - 2.0	7.0	6.2	13.75	H4-H5

based on von Post humification determinations which showed a range, generally H4 to H8, which was considered to be acceptable as fuel peat. However, the laboratory determinations showed that the samples were actually closer to the lower end of the fuel peat spectrum (e.g. H4 to H6).

It may be noted in the raw data presented in Appendix B, that the Parry Sound results were generally more variable than samples taken from the other locations. It is thought that this may have been partly due to lack of experience with the test procedure, since the Parry Sound samples were run first. The USSR information indicates that there is no interference with the determination with ash content up to 15%.

The following three groups of peats with different degrees of decomposition may be described as follows:

a) weak degree of decomposition - up to 20% of highly humified peat;

b) medium degree of decomposition - from 20 to 40% of highly humified peat;

c) high degree of decomposition - more than 40% of highly humified peat.

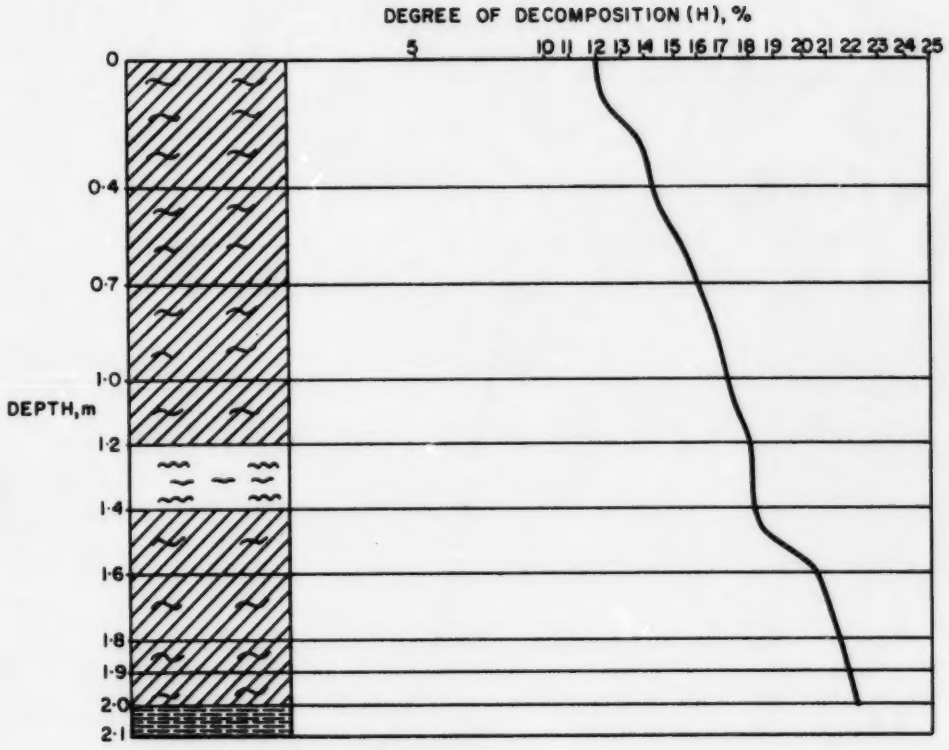
The test results obtained may be grouped in accordance with the above specification. Then the Parry Sound, Ontario (transitional moor) and New York State (lowmoor) peatlands belong to the second group of medium degree of decomposition peat and the Deschambault Lake, Saskatchewan (transitional and lowmoor) and the Inkerman Ferry, New Brunswick (highmoor) are representative of the first group. No samples of the third group were available.

In addition to the aforementioned analysis, the changes in peat degree of decomposition with depth was studied using the Parry Sound, Ontario and Inkerman Ferry, New Brunswick samples. The peat samples from Parry Sound, Ontario were taken at every 10 cm of the peat deposit depth (beginning at 60 cm and down to 190 cm). The degree of decomposition values obtained for this case are plotted in Figure 2-3. A similar distribution of the degree of decomposition values through the peat deposit depth for the Inkerman Ferry, New Brunswick peatland is shown in Figure 2-4. The degree of decomposition increases with peat deposit depth as commonly occurs in most peatlands, although not all.

2.4 COMPARISON OF THE LABORATORY AND von POST RESULTS

Table 2-1 lists both the degree of decomposition percentages and the von Post humification values as determined by the surveyor on portions of the same peat samples. A comparison of the results is made difficult by the intrinsic difference in the methods used.

The field test results are normally assessed according to a category scale (from H1 to 10) depending on the characteristics of the peat squeezed by hand, plant matter of the sample and colour of the water removal. The values of centrifuge degree of decomposition and humification from Table 1-3 are compared graphically in Figure 2-5 including information from a previous correlation by Sarasto of humification versus Pjavtshenko's degree of decomposition. As shown in Figure 2-5, the variation of the centrifuge data, from 9.25% to 13.75%, corresponds to the von Post values of H3 to H5, and values of 11% to 24.3% to von Post values of H6 to H8. It would be premature to make any correlations between the von Post and centrifuge methods based on the relatively small amount of data (44 samples) developed so far.



NOTE: ASH CONTENT OF PEAT AT A DEPTH OF MORE THAN 1·6m WAS AN AVERAGE OF 40%

LEGEND:

- SEDGE-SPHAGNUM PEAT
- SPHAGNUM-SEDGE PEAT
- OOZE

FIGURE 2-3 DISTRIBUTION OF PEAT DEGREE OF DECOMPOSITION VERSUS DEPTH FOR THE PARRY SOUND PEATLAND

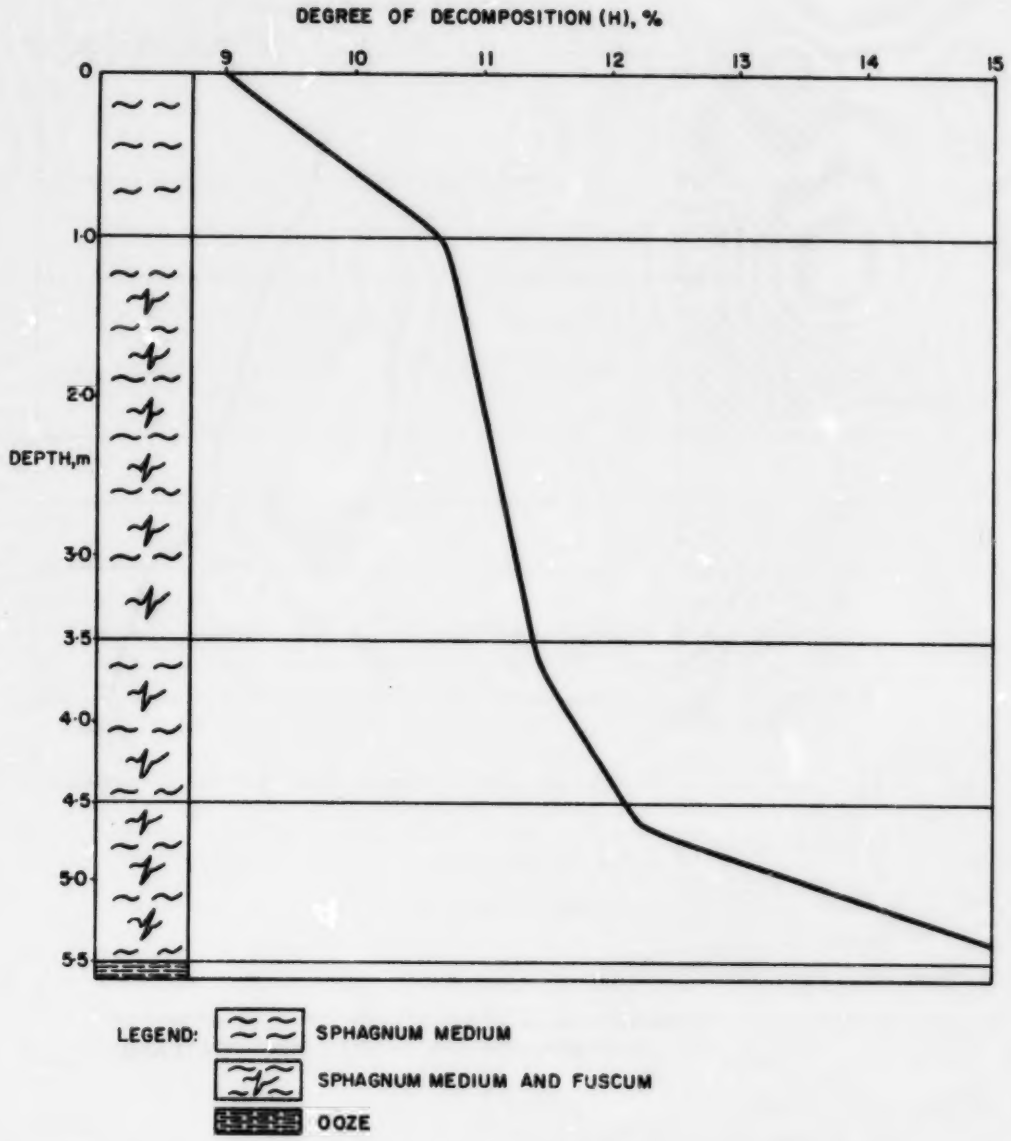


FIGURE 2-4 DISTRIBUTION OF PEAT DEGREE OF DECOMPOSITION VERSUS DEPTH FOR THE INKERMAN FERRY PEATLAND

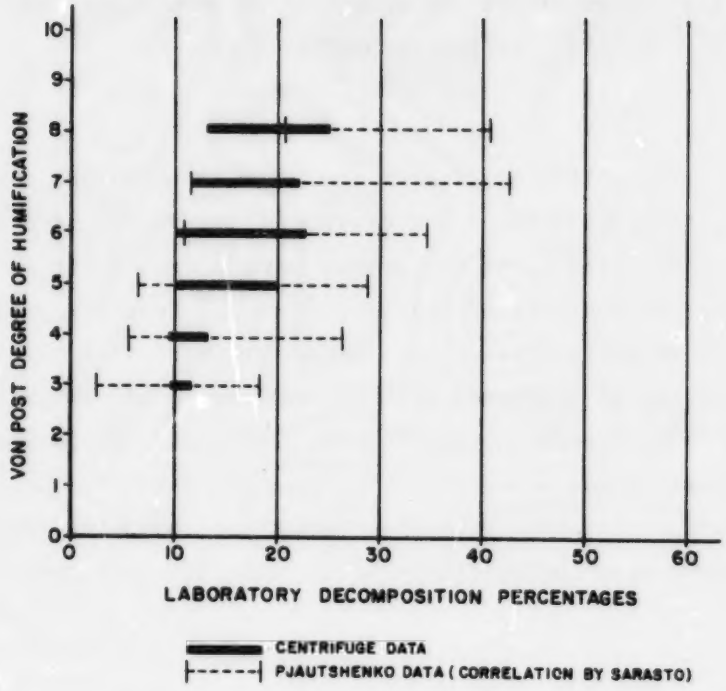


FIGURE 2-5 COMPARISON OF VON POST DEGREE OF HUMIFICATION WITH LABORATORY DECOMPOSITION PERCENTAGES

2.5 COMMENTS ON THE DEGREE OF DECOMPOSITION TEST BY THE LABORATORY (ORF)

The following remarks are taken from the ORF Laboratory Report (No. P-4430/I) on the results of the degree of decomposition tests: "Sampling is of the utmost importance, and it is this task that has the most significant effect on the test's reproducibility. Often it is quite difficult to get a representative sample on which the test can be performed without problems. This is particularly true of the less decomposed peat, though less humified sphagnum peat from New Brunswick was somewhat easier to test than more humified sedge, predominant peat from Ontario. 'Selective' sampling is sometimes necessary, with longer fibers being removed before proceeding with the test."

"The test is as reproducible as can be expected of any test for a substance as variable as peat. For some peats, especially predominantly sedge-sphagnum peat from Ontario, great difficulty was experienced in achieving results within the recommended percentage decomposition limits. In general, a minimum of two runs (eight samples) was required to perform the test successfully."

"The degree of decomposition test is relatively simple to perform. A laboratory centrifuge is the only expensive item required and the procedure is easy to follow. The large centrifuge tubes are not currently available commercially and, along with the sieves, were custom made for this project. With a little practice, one test (4 samples) can be completed within 40 minutes."

"The degree of decomposition test is particularly useful because:

- as a laboratory test method it is less subjective than the normal field tests;

- in contrast to the von Post method, it requires little knowledge of peat characteristics on the part of the technician to perform the test correctly; and

- it does not require expensive equipment.

Because of the difficulties encountered when performing the test on the less humified New Brunswick peat, and the fact that it was not possible to perform the test on two New York sub-samples (surface layer peat), it is felt that the test is less suitable for peat of low humification."

PART 3

PEAT SLURRY VISCOSITY

3.1 INTRODUCTION

As noted in the Monenco report "An Evaluation of Alternative Wet Peat Mining Systems" prepared for NRC in 1983[4], the peat slurry viscosity characteristics have an important effect on many key peat slurry pumping and pipeline transport parameters. It was also reported that the peat slurry viscosity, in turn, depends on the actual qualitative characteristics of peat (peat type, degree of decomposition, ash content, chemical composition, etc.). The aim of the current studies was to confirm this relationship for Canadian types of peat on the basis of laboratory viscosity test results.

The current work is believed to be the first of its kind in North America, i.e., peat slurry viscosity testing on peat samples intended to develop information useful to predict actual industrial peat slurry pumping conditions for certain proposed wet peat mining methods. In particular, it is expected the results of this study will be particularly useful in analysing peat slurry pumping operations where the USSR-style of peat slurry pump/macerator and hydromonitors are employed. It is currently planned to design, fabricate and test a peat slurry pump similar to the former USSR model[5].

A review of the previous literature published in North America revealed that there are few publications on peat slurry rheology in general (6,7,8), and none dealing with the qualitative characteristics of peat in particular. As the peat slurry viscosity values determine the character of main peat mining processes, e.g. peat slurry flow at the pump suction inlet and through the pipelines, it is difficult to overestimate the importance of the viscosity studies for the wet peat mining technology currently being studied by Monenco.

Therefore, the laboratory studies of viscosities pursued the following main objectives:

a) to determine the influence of the qualitative characteristics of peat on peat slurry viscosity;

b) to determine the influence of peat slurry temperature on the peat slurry viscosity characteristics;

c) to study the influence of the extent of peat slurry macerating on peat slurry viscosity characteristics;

d) to determine the influence of solids content on the peat slurry viscosity; and

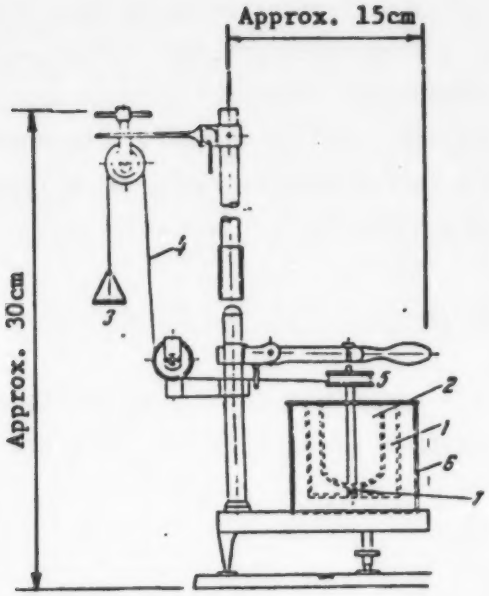
e) to compare the results received for North American types of peat with the information available from the previous USSR experience.

3.2 A LABORATORY METHOD FOR THE DETERMINATION OF PEAT SLURRY VISCOSITY

321 THE USSR VISCOMETER AND CALCULATING METHODS

.1 Summary of Experimental Procedure

The USSR Peat Institute viscosity test methods employ a weight driven viscometer (see Figure 3-1) in which a rotating cylinder is placed in the peat slurry sample. This cylinder rotates between two axle bearings and is driven by variable weights through a series of pulleys. The test cup containing the peat sample is placed in a water bath for temperature control.



1 - Stationary cylinder
2 - Rotaring cylinder
3 - Counterweight
4 - Nylon thread
5 - Pulley
6 - Water reservoir (for water at different temperatures)
7 - Conical bushing

FIGURE 3-1 PEAT RESEARCH INSTITUTE VISCOMETER (U.S.S.R.)

SOURCE: GORJACHKIN, V.G., 1953

Viscosity determination using this viscometer requires sample preparation by a laboratory grinder. Each test sample is divided into a number of sub-samples which are then diluted with water to achieve slurries of different solids contents. Each sub-sample is then tested by applying 5 or 6 different weights and measuring the time for each weight to fall a distance of 2 metres.

.2 Summary of Viscosity Calculating Methods

There are two methods of calculating viscosity based on using the Peat Institute viscometer[2,10]. They are summarized as follows:

Method 1

The conventional viscosity (n) of a peat slurry is determined according to the following formula:

$$n = \frac{P - P_o}{K} \times T \qquad (3\text{-}1)$$

where P = applied weight (grams),

P_o = load required to overcome viscometer friction (grams),

K = a constant for a given viscometer, and

T = time taken for weight to fall (seconds).

NOTE: During the processing of the data received from the use of the Peat Institute viscometer, the value of the maximum shear stress is not taken into account.

"P_o" and "K" are determined for each particular viscometer using a Newtonian liquid such as glycerol or castor oil, of known viscosity.

The peripheral velocity, V_r, of the rotating cylinder of the viscometer is calculated by:

$$V_r = \frac{200 \times D/d \times \P}{T} \quad \text{cm/sec} \qquad (3\text{-}2)$$

where 200 cm = length of unwound silk line,
D = diameter of rotating cylinder (cm),
d = diameter of pulley on which line is wound (cm), and
T = time taken for weight to fall (seconds).

In order to compare results, a coefficient of relative viscosity is introduced. It is determined when the peripheral velocity of the rotating cylinder is equal to 15 cm/sec.

Method 2

Using the same viscometer, the viscosity of a peat slurry may be also calculated by the following formulae:

$$M = \frac{P \times g \times d}{2} \qquad (3\text{-}3)$$

where M = rotating moment,
g = gravitational constant = 9.81 m/sec^2, and
d = diameter of pulley (cm).

$$M = \frac{4 \times \P \times 1 \ (R_1^2 \times R_2^2) \times n \times w}{R_2^2 - R_1^2} \qquad (3\text{-}4)$$

where l = height of the internal rotating cylinder submerged in the slurry (cm),

w = angular velocity of the internal rotating cylinder = $2\pi N$; where N = internal cylinder revolutions per second,

R_1 = radius internal cylinder (cm), and

R_2 = radius external cylinder (cm).

Viscosity is then determined as:

$$n = K \times P \times T \tag{3-5}$$

where K = a constant for the given viscometer, determined as

$$K = \frac{D \times (R_2^2 - R_1^2) \times g}{16\pi^2 \times R_1^2 \times R_2^2 \times l} \tag{3-6}$$

T = the period of rotation; $T = \frac{1}{N}$

The peripheral velocity "V_r" of the internal rotating cylinder is:

$$V_r = \frac{S}{t} \text{ cm/sec} \tag{3-7}$$

where S = distance travelled by some marked point on the surface of the internal rotating cylinder for the period "T" (cm), and

t = the period time (seconds) required for the applied weight to drop 2 meters.

Both methods are essentially the same, relating applied load and time to viscosity, and distance travelled by the falling weight and time to velocity. Method 1 was used until the late 1940's, and superseded by Method 2 as reported in the literature in the 1950's.

322 VISCOMETER SELECTION FOR THE VISCOSITY TESTS

There are a variety of commercially available viscometers including the Brookfield, Saybolt, Fann, Cannon-Fenske and Thomas-Stormer. In reviewing the design and operation of the viscometers it was decided that the Thomas-Stormer (Figure 3-2) reflected most closely the critical points of operation and design of the Peat Institute viscometer. It was preferred over other available models for use in this experimental program for the following reasons:

a) the methods of calibration for both the Thomas-Stormer and Peat Institute viscometers are similar;

b) the Thomas-Stormer laboratory test procedure is similar to the Peat Institute procedure;

c) both viscometers employ a rotating cylinder mechanism and pulley and weight arrangement to measure viscosity;

d) data on the speed of the rotating cylinder is required for correlation to slurry flow velocity (as discussed further in Part 4) and was available from the Thomas-Stormer model; and

e) the viscosity results of the Thomas-Stormer can be compared with data obtained using the Peat Institute viscometer.

The Thomas-Stormer viscometer, which is applicable to a wide variety of industrial materials including inks, oils, muds, tars, paints and starch suspensions, was used in the experimental program. Its viscosity measurement procedure is based on the rate of rotation of a standard cylindrical rotor immersed in the sample and impelled by a uniform force at a specific temperature. The cylinder is driven by

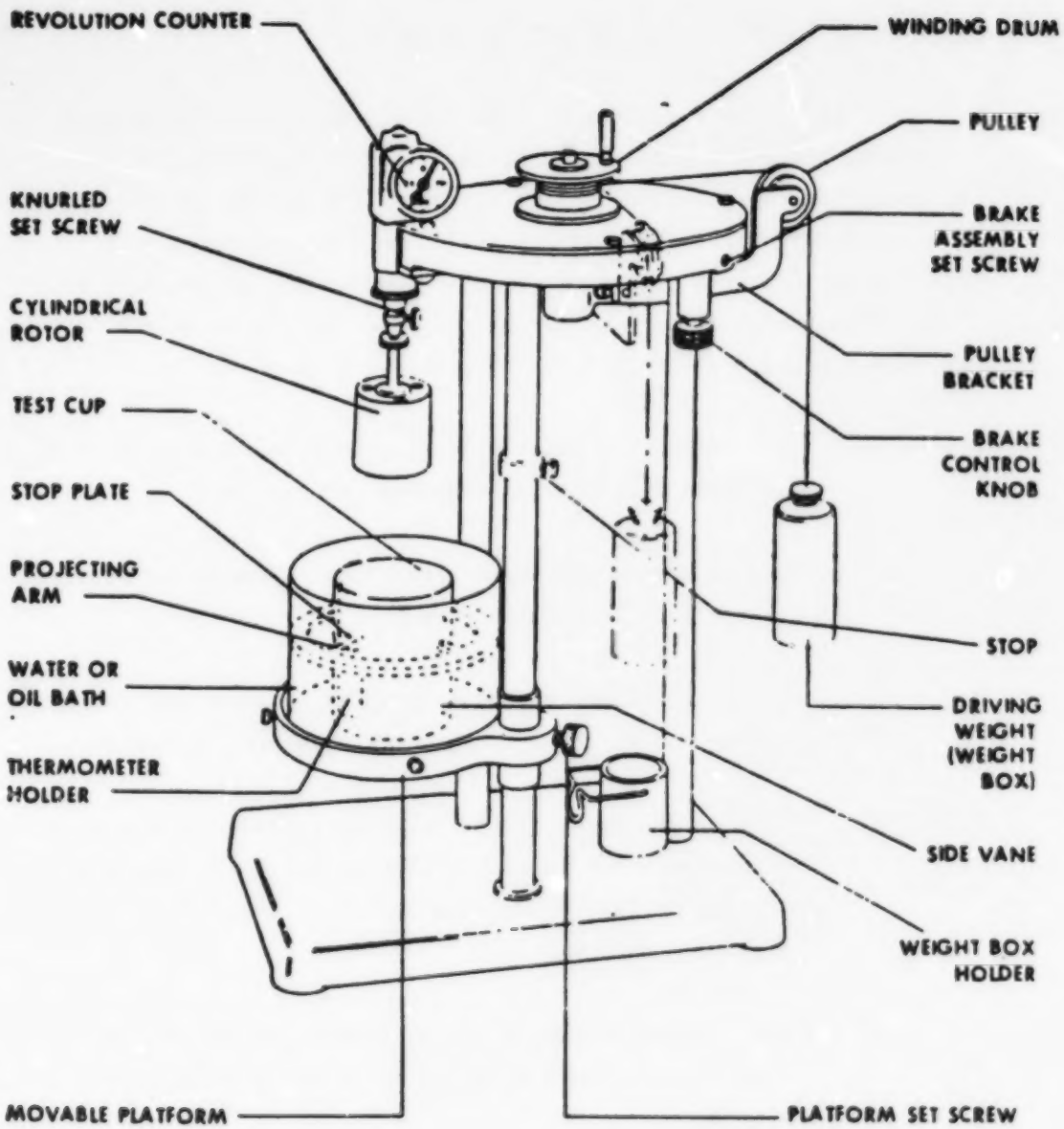


FIGURE 3-2 THOMAS-STORMER VISCOMETER-SILICATE OUTFIT (9730-F40)
Reference: Technical Manual, Arthur H. Thomas Company
Philadelphia, PA 19105, USA.

a falling weight supported over a pulley by a light string, which is in turn, wound about a vertical central spindle, and by a rotating gear which drives the shaft of the standard cylinder. The driving gear is held by a thumbscrew stop which releases the weight coincident with starting of time. The shaft of the rotor is fitted with a revolution counter. The test cup has two side vanes, and temperature can be controlled by means of a water bath.

The most apparent difference between the two viscometers is the power transmission design of the Thomas-Stormer. It includes a small gearbox, while the Peat Institute model operates through a series of pulleys.

The Thomas-Stormer viscometer would seem to be at least as accurate as the Brookfield and may well be more suitable for measuring the viscosity of peat. However, the Brookfield viscometer is a far more convenient and easy to operate unit whose suitability for this particular application should be studied in greater detail.

To summarize, while being simple in theory, ORF reported the test to be quite labour intensive, particularly for peat which often requires a number of attempts before a reading can be made. The viscometer was not designed specifically for peat analysis and was reported to be exasperating at times for the operator.

323 PEAT VISCOSITY DETERMINATIONS USING THE THOMAS-STORMER VISCOMETER

.1 Method of Calculation

The method of calculation recommended for the Thomas-Stormer viscometer resembles closely the Peat Institute calculating Method 2. The constant (K) for the viscometer was calculated using aqueous glycerol solutions of known viscosities at 25°C. Calibration graphs

are shown in Appendix C. The load required to overcome friction was determined to be negligible.

The formula used throughout the test program was:

$$n = P \times T \times K \qquad (3\text{-}8)$$

where n = viscosity (cps),
P = load (gram),
T = time for 100 revolutions (seconds), and
K = a constant for the viscometer = 0.08475.

Peripheral viscosity V_r (cm/sec) of the rotating cylinder was calculated as:

$$V_r = \frac{2 \times \P \times R \times 100}{T} \qquad (3\text{-}9)$$

where R = radius of rotating cylinder, = 1.5875 cm, and
T = time for 100 revolutions (seconds).

The following is a description of the apparatus and method employed in the study to determine the viscosity of various peat slurries over a range of solids contents.

.2 Test Procedure

Apparatus

- Thomas-Stormer (Silicate Outfit) Viscometer (9730 - F40 Series), and

- two kitchen meat grinders were used, one with a 4 mm diameter die and the other with a 7 mm diameter die (see Figure 3-3).

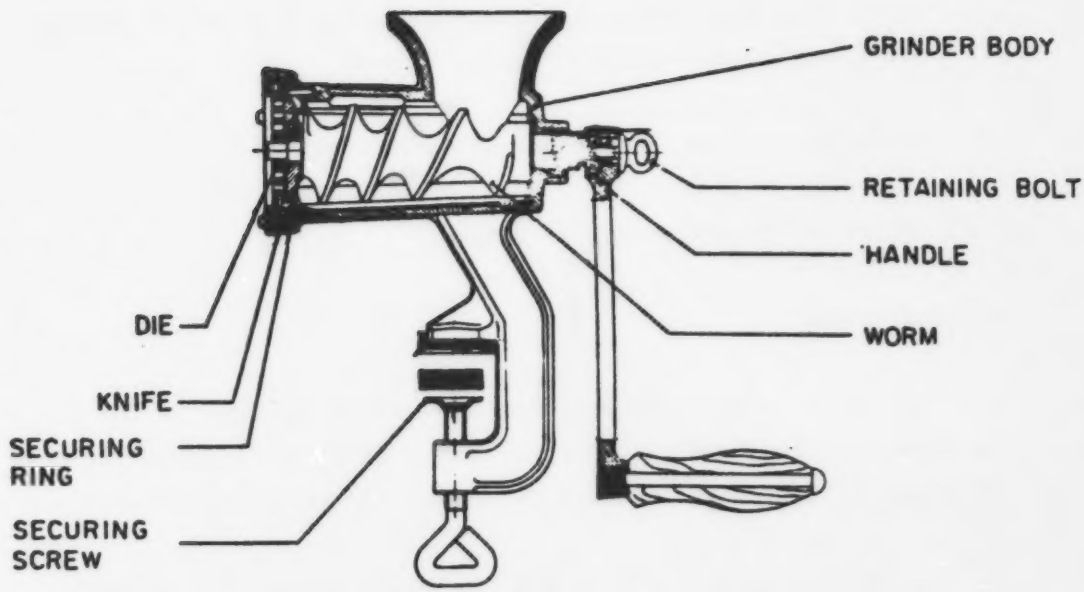


FIGURE 3-3 LABORATORY GRINDER

Sample Preparation

1. Approximately 500 grams (if available) of well mixed peat sample was ground through either the 4 or 7 mm die grinders.

2. The solids contents of each sample were determined by calculating the moisture content according to the gravimetric method outlined in the NRC Peat Testing Manual.

3. From the results, the weight of water required to make up peat slurries of 2.8%, 3.3%, 3.6%, 3.9% and 4.2% solids was calculated based on 100 grams of peat sample.

Viscosity Test

An outline of the test procedure as recommended by the manufacturers of the Thomas-Stormer viscometer is given in Appendix D. This was the procedure followed throughout the testing program.

To summarize, testing was carried out by placing approximately 90 mL of well shaken peat slurry sample in the test cup. A range of weights were applied with a target time for 100 revolutions of 20 to 150 seconds. The slurry sample temperature was maintained with an accuracy of ±1°C using a water bath, with dry ice when required. Using a Thomas-Stormer viscometer, ORF determined the viscosity of over 140 different slurries. The viscosity and rotating cylinder velocity values were calculated based on the measured values of load and time.

3.3 RESULTS OF THE LABORATORY ANALYSES OF PEAT SLURRY VISCOSITIES

331 VISCOSITY TEST RESULTS

Tables 3-1, 3-2, 3-3 and 3-4 summarize the results of the conventional viscosity determinations on the Ontario, New York, New Brunswick and Saskatchewan peat samples, respectively. Appendix "E" contains further details on the individual test results.

From the results of the ORF laboratory tests, the following correlations were determined:

a) between the qualitative peat characteristics and the peat slurry viscosity;

b) between the peat slurry temperature and the peat slurry viscosity;

c) between the peat slurry maceration and the peat slurry viscosity;

d) between the peat slurry solids content and the peat slurry viscosity; and

e) between North American and Russian peat slurry viscosity values.

The detailed description of each relationship follows.

TABLE 3-1

Conventional Viscosity Characteristics for Parry Sound Samples (Ontario)
Transitional moor Peatland, Sedge-Sphagnum & Sphagnum-Sedge Peat Types

Solids Content of Peat Slurry Samples, % (by weight)					Conventional Viscosity*, Centipoise															
					4 mm Size Sieve of Lab Grinder										7 mm Size Sieve of Lab Grinder					
					2.80		3.30		3.60		3.90		4.20		2.80		3.30		3.60		3.90		4.20	
Temperature, °C					10	20	1	15	10	20	1	15	10	20	10	20	1	15	10	20	1	15	10	20
Sample No.	Bog No.	Degree of Decomp. %	Ash Content %	pH																				
1	Ont. 1	16.2	6.06	3.71	65	60	85	63	85	75	130	105	215	205	100	70	150	80	160	130	155	120	270	210
2	Ont. 1	17.8	13.44	3.96	65	60			120	85			150	130	100	60	155	125	195	150			250	190

Solids Content of Peat Slurry Sample, % (by weight)					2.8			4.2			2.8			4.2		
Temperature, °C					1	10	20	1	10	20	1	10	20	1	10	20
3	Ont. 1	18.2	41.27	4.45	75	70	65	225	100	90	100	65	60	230	180	155

*The conventional viscosity is determined when the peripheral velocity of the rotating cylinder is equal to 15 cm/sec.

TABLE 3-2

Conventional Viscosity Characteristics for New York State Peat Samples
Lowmoor Peatlands, Wood-Sedge and Sedge-Sphagnum Peat Types

Solids Content of Peat Slurry Samples, % (by weight)					Conventional Viscosity*, Centipoise																	
					4 mm Size Sieve of Lab Grinder										7 mm Size Sieve of Lab Grinder							
					2.80		3.30		3.60		3.90		4.20		2.80		3.30		3.60		3.90		4.20	
Temperature, °C					10	20	1	15	10	20	1	15	10	20	10	20	1	15	10	20	1	15	10	20
Sample No.	Bog No.	Degree of Decomp. %	Ash Content %	pH																				
1	N.Y. 2	19.8	1.7	3.8	95	70	150	115	275	155	285	235	420	300	93	68	125	100	275	250	305	250	400	300
2	N.Y. 1	20.4	2.7	3.8	85	65	160	125	170	150	275	245	295	275	100	90	120	100	280	265	220	215	340	300
3**	N.Y. 1	-	8.6	3.7	40	35	45	35	40	30	50	45	55	50	45	40	63	55	70	65	100	85	125	115
4	N.Y. 1	13.3	2.6	3.7	65	60	110	100	100	115	230	150	215	205	110	95	225	190	275	260	390	325	310	300
5**	N.Y. 3	-	15.2	6.3	25	20	35	30	35	25	45	35	45	40	35	35	55	40	65	65	70	60	80	70
6	N.Y. 3	22.3	15.7	6.3	35	30	40	35	45	40	65	55	65	55	35	30	45	40	50	40	60	55	80	65
7	N.Y. 4	22.2	14.3	6.4	35	30	65	60	60	40	75	70	70	60	35	30	40	35	40	40	55	45	55	50

*The conventional viscosity is determined when the peripheral velocity of the rotating cylinder is equal to 15 cm/sec.
**Unable to perform the degree of decomposition test on this sample.

TABLE 3-3

Conventional Viscosity Characteristics for Inkerman Ferry Peat Samples (New Brunswick)
Highmoor Peatland, Sphagnum Medium and Sphagnum (mixed) Peat Types

Solids Content of Peat Slurry Samples, % (by weight)					Conventional Viscosity*, Centipoise									
					4 mm Size Sieve of Lab Grinder					7 mm Size Sieve of Lab Grinder				
					2.80	3.30	3.60	3.90	4.20	2.80	3.30	3.60	3.90	4.20
Temperature, °C					10	10	10	10	10	10	10	10	10	10
Sample No.	Bog No.	Degree of Decomp. %	Ash Content %	pH										
1	N.B. I	9.3	1.0	3.39	195	360	505	550	930	380	650	920	1130	1650
2**	N.B. I	-	2.5	3.81	-	-	-	-	-	-	-	-	-	-
3	N.B. I	10.5	0.6	3.42	-	-	-	-	-	85	190	275	390	560
4	N.B. I	11.5	1.1	3.75	125	260	450	550	585	290	360	530	860	1500
5**	N.B. I	11.0	3.0	3.74	-	-	-	-	-	125	240	375	480	620
6	N.B. I	14.0	3.0	3.93	-	-	-	-	-	70	140	320	350	370

*The conventional viscosity is determined when the peripheral velocity of the rotating cylinder is equal to 15 cm/sec.
**Unable to perform the degree of decomposition test on this sample.

TABLE 3-4

Conventional Viscosity Characteristics for Deschambault Lake Peat Samples (Saskatchewan)
Transitionalmoor and Lowmoor Peatland, Sedge-Sphagnum Peat Types

Solids Content of Peat Slurry Samples, % (by weight)					Conventional Viscosity*, Centipoise				
					7 mm Size Sieve of Lab Grinder				
					2.80	3.30	3.60	3.90	4.20
Temperature, °C					10	10	10	10	10
Sample No.	Bog No.	Degree of Decomp. %	Ash Content %	pH					
1	Sask. 1	12.50	7.2	5.77	35	38	41	45	55
2	Sask. 1	12.25	6.5	6.04	50	100	125	165	215
3	Sask. 1	13.75	7.0	6.24	50	105	140	200	310

*The conventional viscosity is determined when the peripheral velocity of the rotating cylinder is equal to 15 cm/sec.

332 A CORRELATION BETWEEN QUALITATIVE PEAT CHARACTERISTICS AND PEAT SLURRY VISCOSITY

Peat slurry samples from the following Canadian and U.S. peat deposits were studied:

- Parry Sound (Ontario), transitional moor peatland;
- Folley Bog, Fort Drum test site and bog, JJ4-2 (New York State), lowmoor peatlands;
- Inkerman Ferry (New Brunswick), highmoor peatland; and
- Deschambault Lake (Saskatchewan), transitional moor and lowmoor peatland.

.1 Type of Peat

The laboratory tests showed that the various types of peat have their own unique viscosity characteristics. Table 3-5 compares the viscosity results for the various peat types and other peat quality characteristics. The graphs of peat slurry viscosity versus peripheral velocity of the rotating cylinder of the viscometer is shown in Figure 3-4 for the various peat types. In Table 3-5 and Figure 3-4, the peat slurry viscosity characteristics are determined by the type of peat or, in other words, by its chemical composition which, in turn, is determined by the peat-forming plants and the conditions of peat formation (atmospheric, temperature, water balance, etc.) at the given peatland.

.2 Degree of Decomposition

The laboratory tests showed that the degree of decomposition of the peat samples had a significant effect on the peat slurry

TABLE 3-5

Comparison of Viscosity Results for Different Types of Peat
(2.8 to 4.2% solids content of peat slurry)

PEATLAND SAMPLES	PEAT TYPE CLASSIFICATION	Average Values Over Depth Interval				
		DEPTH OF SAMPLED LAYERS (m)	DEGREE OF DECOM-POSITION (%)	ASH CONTENT (%)	pH	RANGE OF VISCO-SITIES cps
Parry Sound, Ontario	Transitional moor	0.6-1.9	17	20.0	4.0	60-270
New York State	Lowmoor	0-3.2	22	8.7	5.1	30-400
Inkermann Ferry, N.B.	Highmoor	0-5.5	12	1.9	3.7	70-1650
Deschambault Lake, Saskatchewan	Transitional moor & Lowmoor	0.5-2.0	13	6.9	6.0	35-310

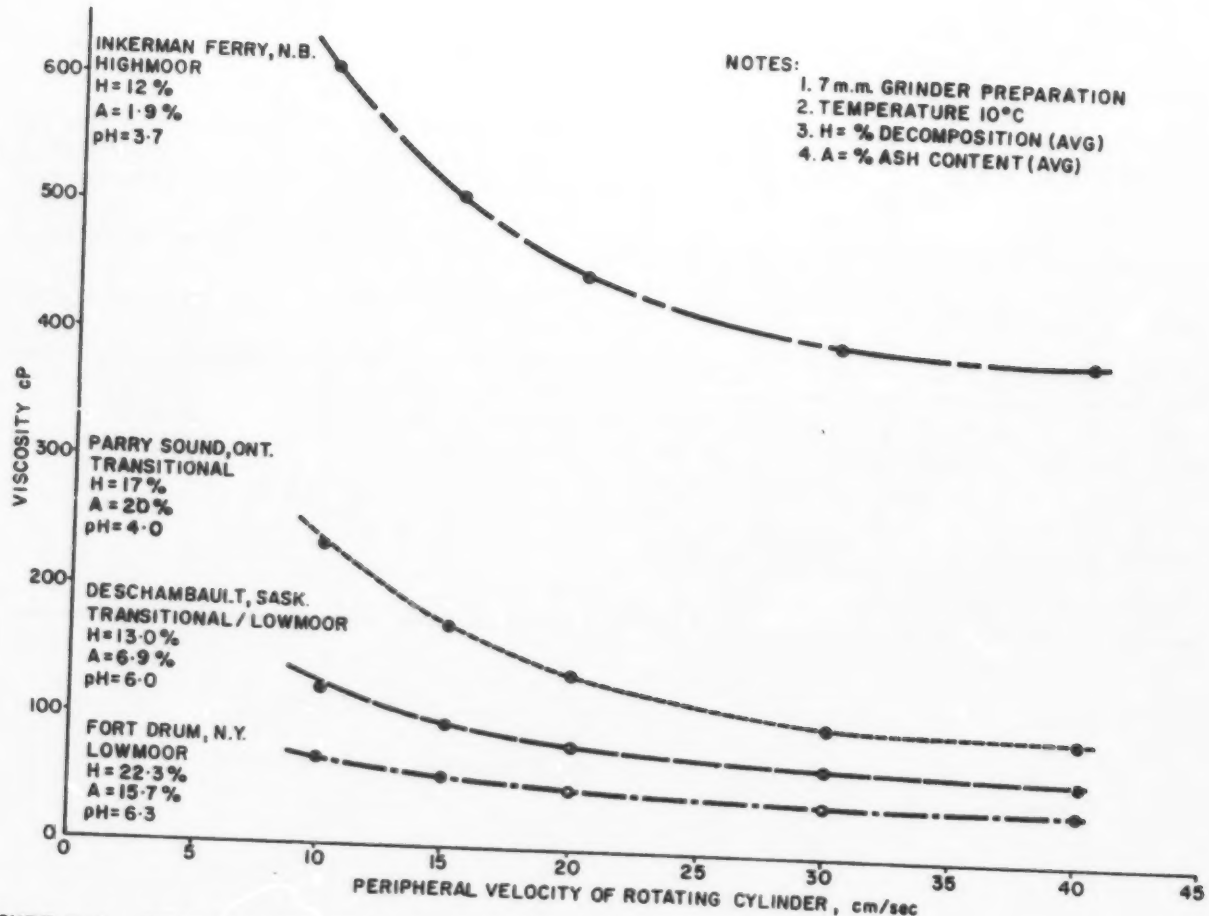


FIGURE 3-4 PEAT SLURRY VISCOSITY CHARACTERISTICS FOR DIFFERENT PEAT TYPES AT 3·6 % SOLIDS CONTENT

viscosity characteristics (Tables 3-1 to 3-4). This effect is demonstrated by example as shown in Figure 3-5 for the New York State peat samples which had the widest variation of degree of decomposition (sample No. 4 with 13.3% and sample No. 6 with 22.3% degrees of decomposition). It is clear from Figure 3-5 that the peat viscosity decreases with an increase in the degree of decomposition. The USSR information also shows this to be the case, based on a vast amount of data accumulated over many years. Due to the preliminary nature of the current work, i.e., a relatively minor number of samples studied, there was an insufficient variation in the samples of the other types of peat to further demonstrate this relationship.

.3 Ash Content

The laboratory testing program did not include studies of the relationship between ash content of the peat and peat viscosity since the effects of ash content and degree of decomposition on peat viscosity are interdependent. To single out the ash content effect separately, samples of the same type of peat with a constant degree of decomposition, but with different ash contents, are required. Unfortunately, due to the preliminary nature of the current program, such samples were not available and although the ash content ranged from 1.9 to 20% as shown in Table 3-5, the values of ash content could not be compared for different types of peat.

333 RELATIONSHIP BETWEEN PEAT SLURRY TEMPERATURE AND THE PEAT SLURRY VISCOSITY

The laboratory tests showed that the temperature of the peat slurry samples had a significant effect on the peat slurry viscosity characteristics. This effect is demonstrated by the example as shown in Figure 3-6 for the Parry Sound sample No. 3. The curves demonstrate clearly that the lower the peat temperature, the higher its viscosity. The relationship is also quite apparent from the viscosity values presented in Table 3-1.

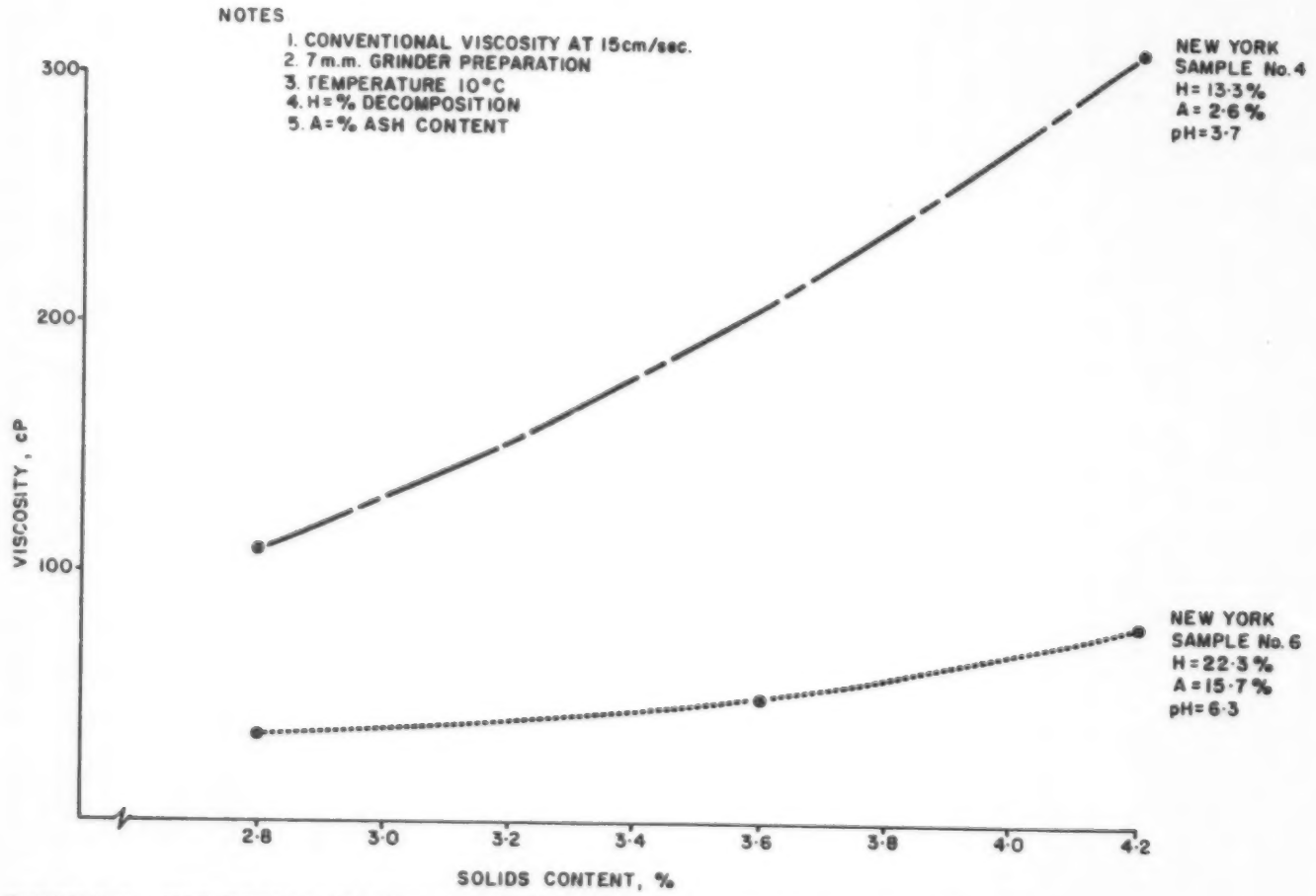


FIGURE 3-5 THE EFFECT OF DEGREE OF DECOMPOSITION ON VISCOSITY FOR NEW YORK PEAT SAMPLES (LOWMOOR PEATLAND)

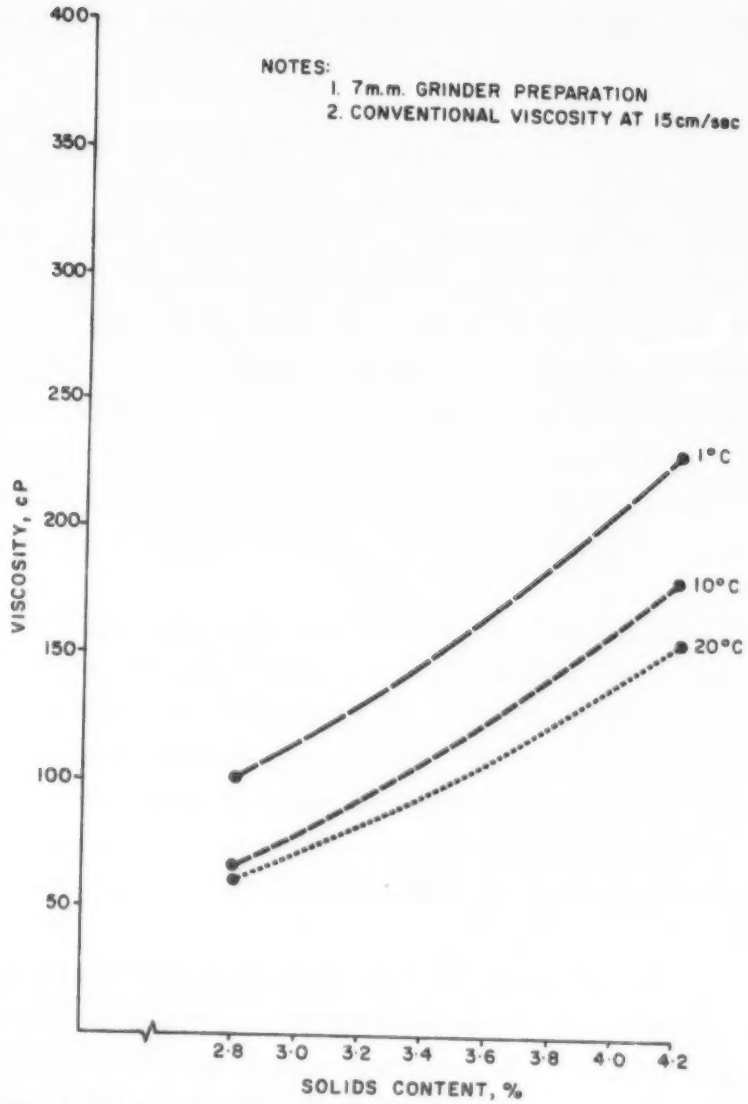


FIGURE 3-6 THE EFFECT OF TEMPERATURE ON PEAT SLURRY VISCOSITY FOR PARRY SOUND (ONTARIO) SAMPLE No.3

334 EFFECT OF PEAT SLURRY MACERATION (SAMPLE PREPARATION) ON PEAT SLURRY VISCOSITY

Processing of the peat slurry is an important factor in the pumping of peat slurry, especially peat of a low degree of decomposition (15-20%). The raw peat samples were initially ground using either a 4 mm or 7 mm die standard kitchen-type meat grinder. The purpose of this treatment step was to prepare a peat slurry with similar properties to that which would be produced by a peat pump/macerator in a full-scale or industrial set-up. This was also the recommended sample preparation procedure for the Peat Institute viscometer test. The effects of sample preparation on the peat slurry viscosity is shown in Figure 3-7.

The 4 mm grinder gave a finer grinding than the 7 mm one, and produced a less viscous slurry. The effect is demonstrated by the examples as shown in Figure 3-7. In Figure 3-7, the high moor peat, such as the New Brunswick sample No. 1, most readily demonstrates the relationship. With more well-humified peat, as shown in Table 3-2, the effect of grinding on peat slurry viscosity is less noticeable; this is particularly true for some of the New York samples.

The effect of using the 4 mm and 7 mm grinders in sample preparation was assessed by doing particle size analyses on two New Brunswick peat samples. The results are presented in Table 3-6. As is shown, a 4 mm grinder gives a greater maceration effect (particle sizes are smaller - more peat passes through the larger sieves) than with a 7 mm grinder.

335 RELATIONSHIP BETWEEN PEAT SLURRY SOLIDS CONTENT AND THE PEAT SLURRY VISCOSITY

The studies of the peat slurry viscosity characteristics were carried out for peat slurries with 2.8% to 4.2% solids content. The

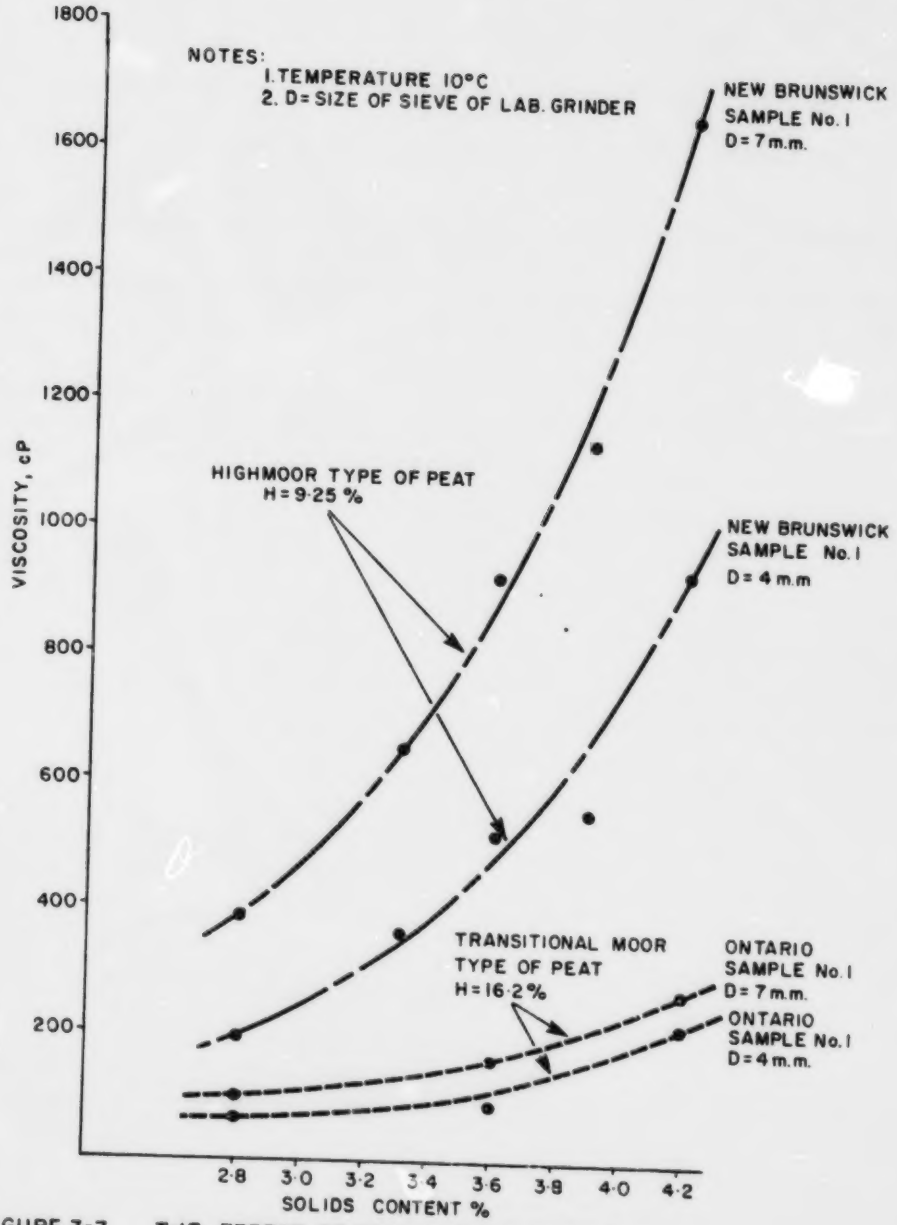


FIGURE 3-7 THE EFFECT OF PEAT SAMPLE PREPARATION ON SLURRY VISCOSITY FOR HIGHMOOR AND TRANSITIONAL MOOR TYPES OF PEAT

TABLE 3-6

Particle Size Distribution on Inkerman Ferry Peatland
(New Brunswick)
Samples Nos. 1 and 4 with 4 mm and 7 mm Grinder Preparation

Sample	Sieve	Particle Size	Percentage
NB #1 (4 mm)	10	>2 mm	0.6
	18	>1 & <2	1.6
	30	>0.6 & <1	5.7
	100	>0.149 & <0.6	49.9
	230	>0.063 & <0.149	9.9
		Unaccounted for*	32.3
NB #1 (7 mm)	10	>2 mm	2.0
	18	>1 & <2	3.0
	30	>0.6 & <1	6.6
	100	>0.149 & <0.6	52.1
	230	>0.063 & <0.149	8.7
		Unaccounted for*	27.6
NB #4 (4 mm)	10	>2 mm	0.5
	18	>1 & <2	1.4
	30	>0.6 & <1	3.6
	100	>0.149 & <0.6	45.3
	230	>0.063 & <0.149	9.6
		Unaccounted for*	39.6
NB #4 (7 mm)	10	>2 mm	0.7
	18	>1 & <2	2.5
	30	>0.6 & <1	30.3
	100	>0.149 & <0.6	18.0
	230	>0.063 & <0.149	3.3
		Unaccounted for*	45.2

*Colloidal

selection of this range of solids concentration was not arbitrary. It was due to the following reasoning:

a) more than 40 years of industrial experience in the USSR indicated that the expected average solids content of peat slurry would be within the 2.8% - 4.2% limits;

b) a method of peat mining as designed by Monenco is based on similar mining operations with an expected solids concentration of the same magnitude for Canadian types of peat;

c) It was assumed that Canadian peat types would show analogous rheological features as similar peat types in the USSR;

d) information available to Monenco indicated that the major mining and pumping parameters (length and diameter of pipeline, dynamic head required, friction losses, required pump capacity, etc.) required for high efficiency of wet peat mining operations occur when the solids concentration is within the range 3% to 4.5%; and

e) to be able to compare the viscosity characteristics of the Canadian and U.S. peat types obtained from the Thomas-Stormer viscometer during laboratory tests with similar results for the USSR types of peat determined by the Peat Institute viscometer.

The viscosity curves for the different peat samples at varying solids content and velocity of viscometer rotating cylinder are shown in Figures 3-8 to 3-16, inclusive. The curves demonstrate a similar trend; for all levels of solids concentration, the viscosities increase at lower cylinder velocities. Also it is clearly shown that

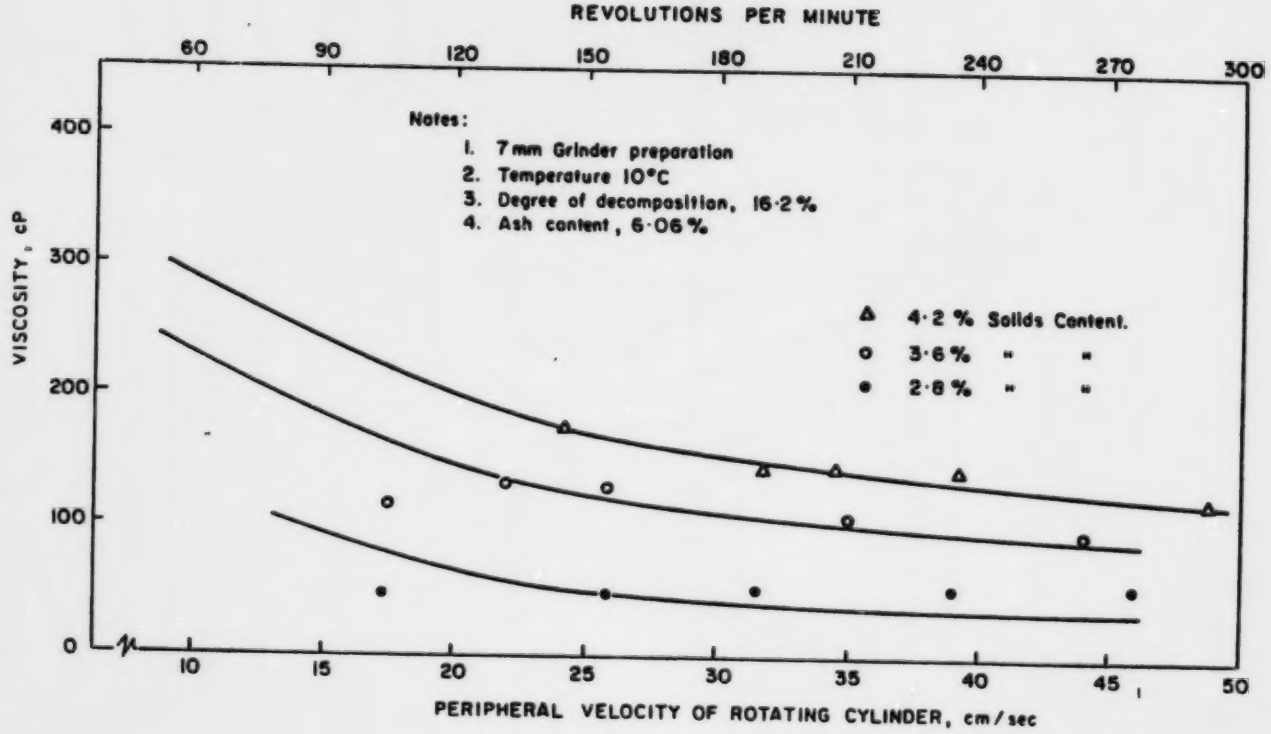


FIGURE 3-8 PEAT SLURRY VISCOSITY CHARACTERISTICS AT DIFFERENT SOLIDS CONTENT FOR ONTARIO PEAT SAMPLE No.1 , 0·6 - 1·2 m DEPTH.

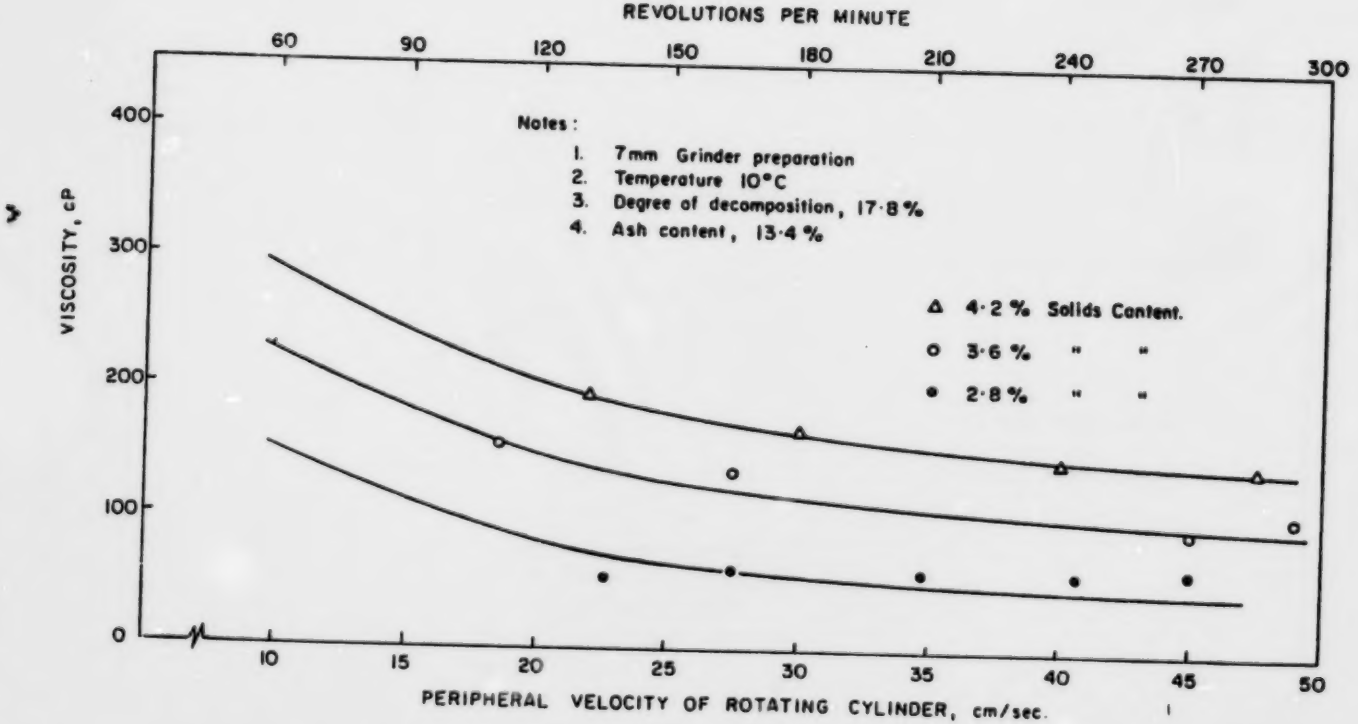


FIGURE 3-9 PEAT SLURRY VISCOSITY CHARACTERISTICS AT DIFFERENT SOLIDS CONTENT FOR ONTARIO PEAT SAMPLE No.2., 1·2 – 1·6 m DEPTH.

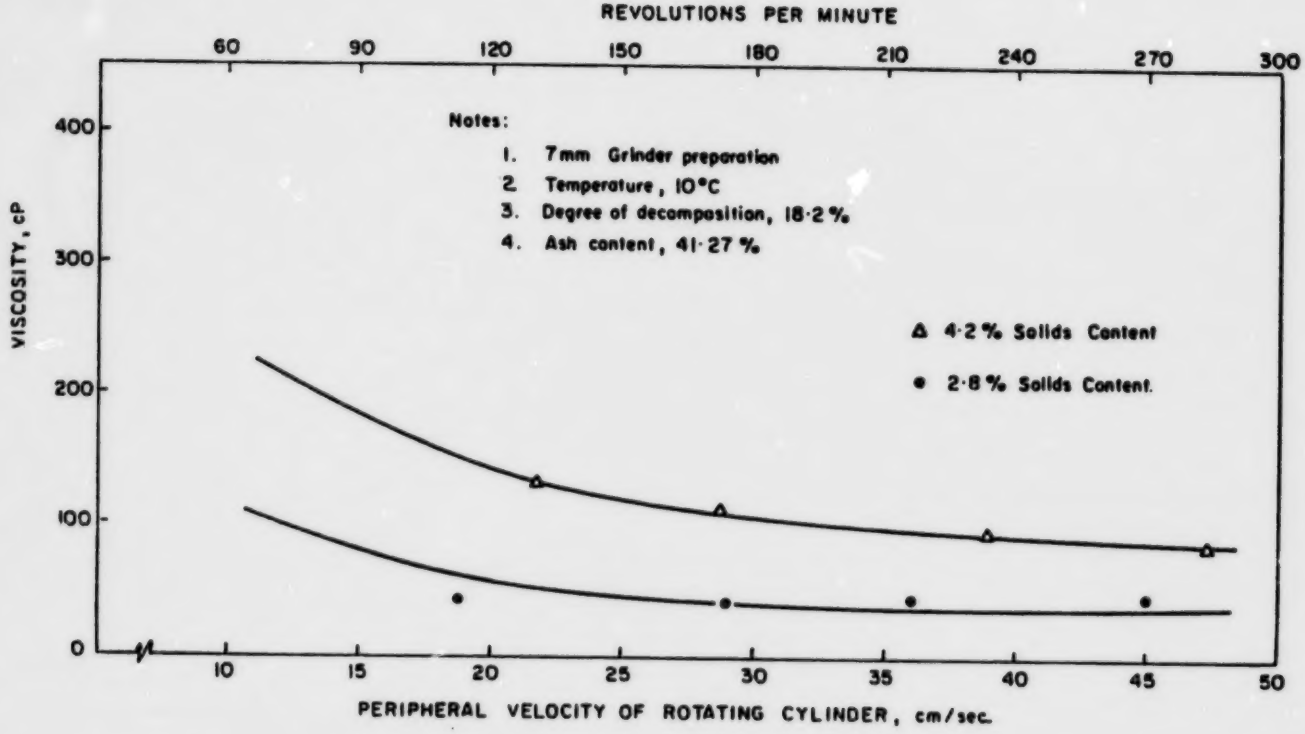


FIGURE 3-10 PEAT SLURRY VISCOSITY CHARACTERISTICS AT DIFFERENT SOLIDS CONTENT FOR ONTARIO PEAT SAMPLE No. 3, 1·6 - 1·9 m DEPTH.

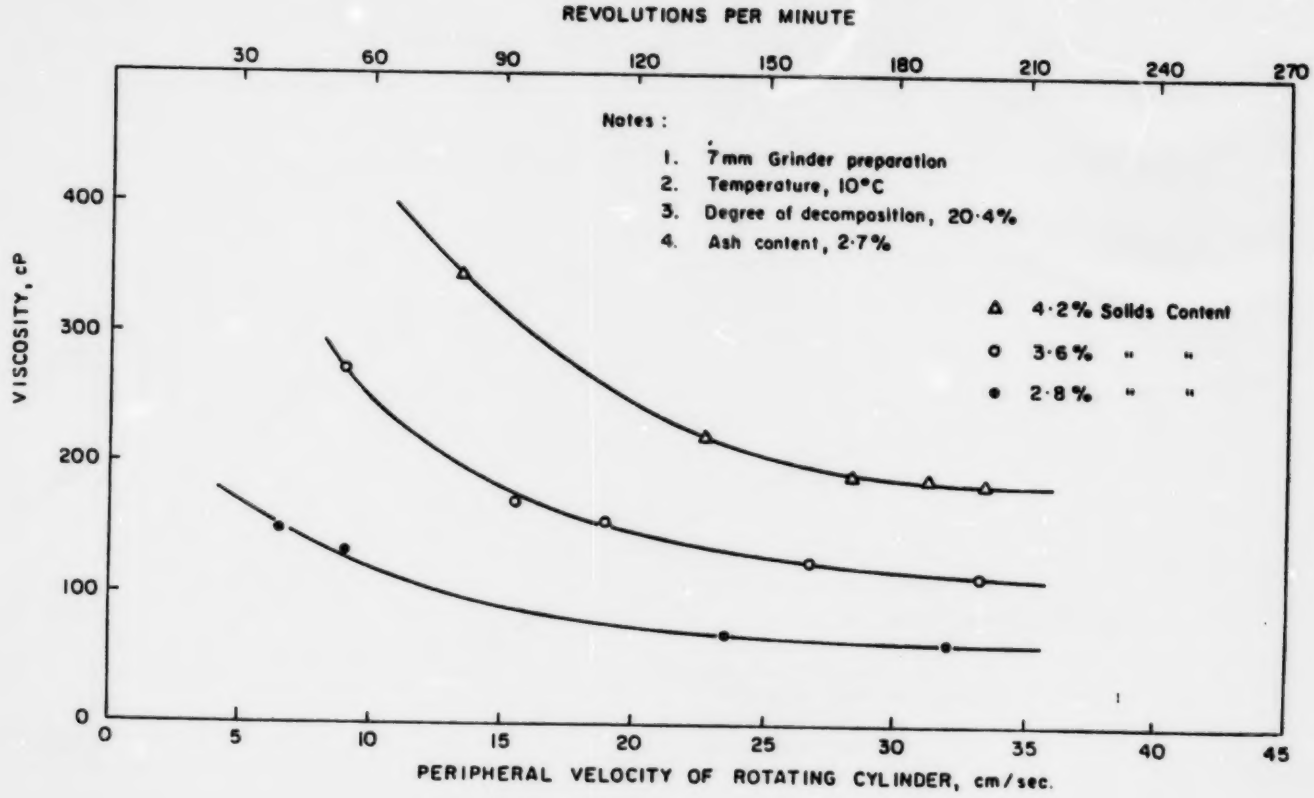


FIGURE 3-11 PEAT SLURRY VISCOSITY CHARACTERISTICS AT DIFFERENT SOLIDS CONTENT FOR NEW YORK BOG No.1 (SAMPLE No.2, 0-3·5M DEPTH)

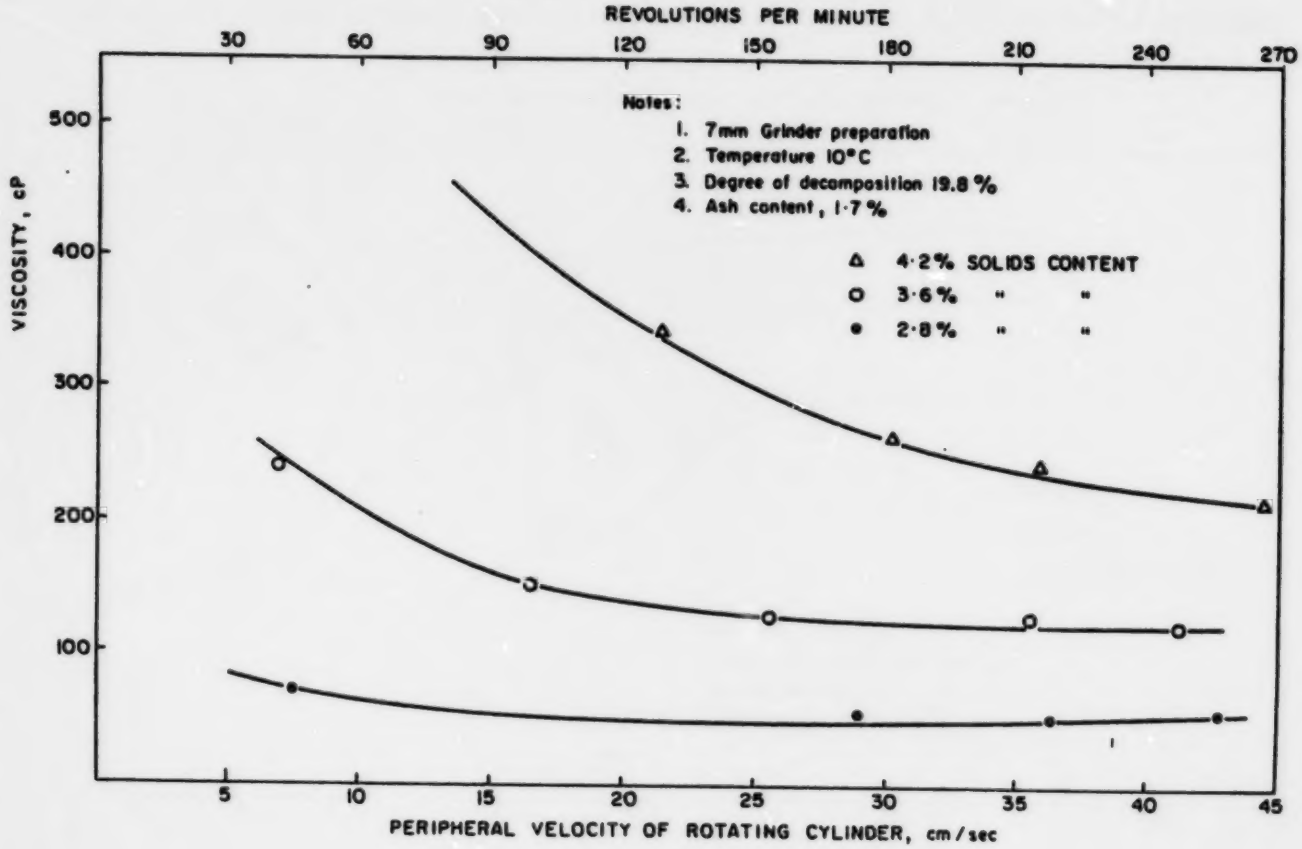


FIGURE 3-12 PEAT SLURRY VISCOSITY CHARACTERISTICS AT DIFFERENT SOLIDS CONTENTS FOR NEW YORK BOG No.2 (Sample I., 0 - 3·5 m DEPTH)

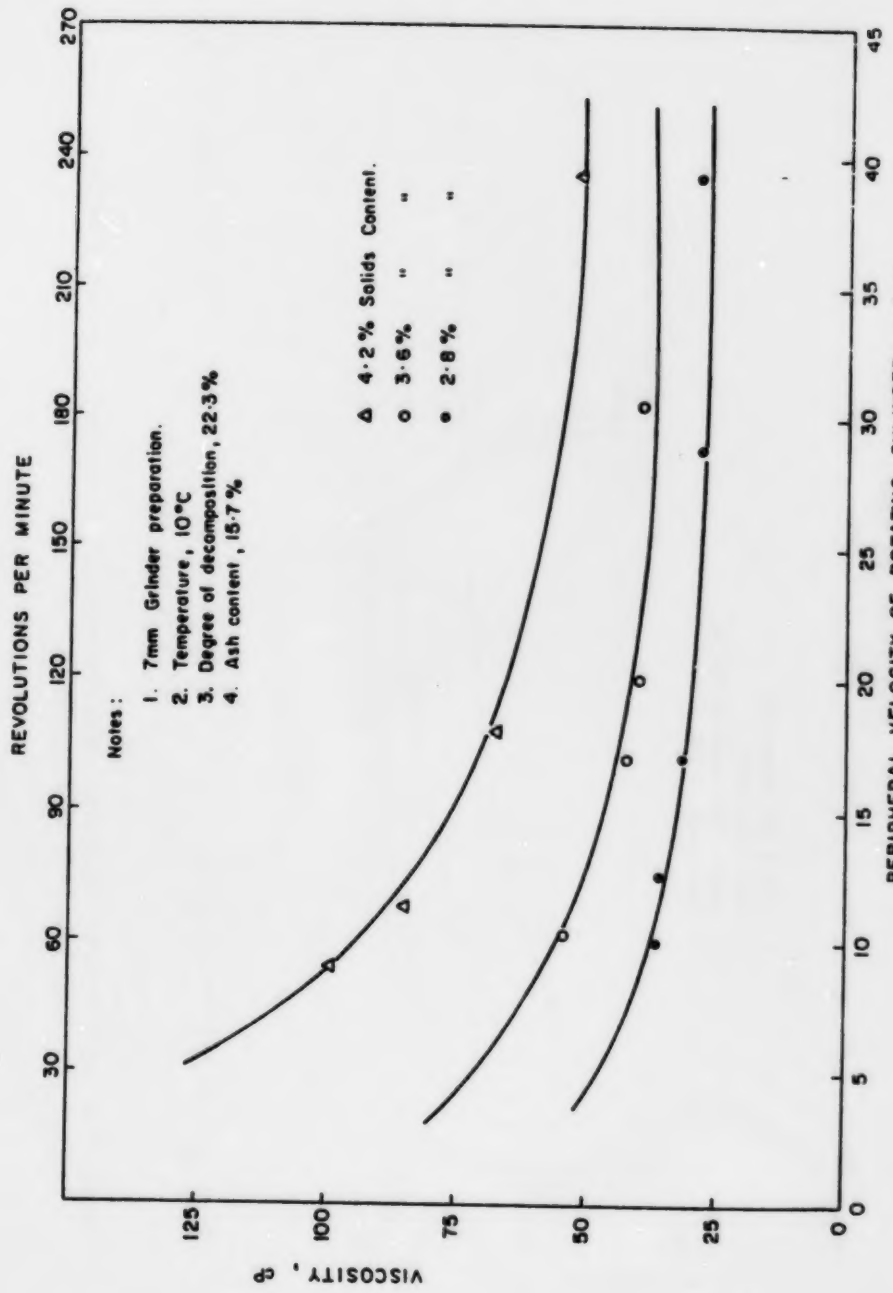


FIGURE 3-13 PEAT SLURRY VISCOSITY CHARACTERISTICS AT DIFFERENT SOLIDS CONTENT FOR NEW YORK BOG No. 3 (SAMPLE No.6 , 0-3·5m DEPTH)

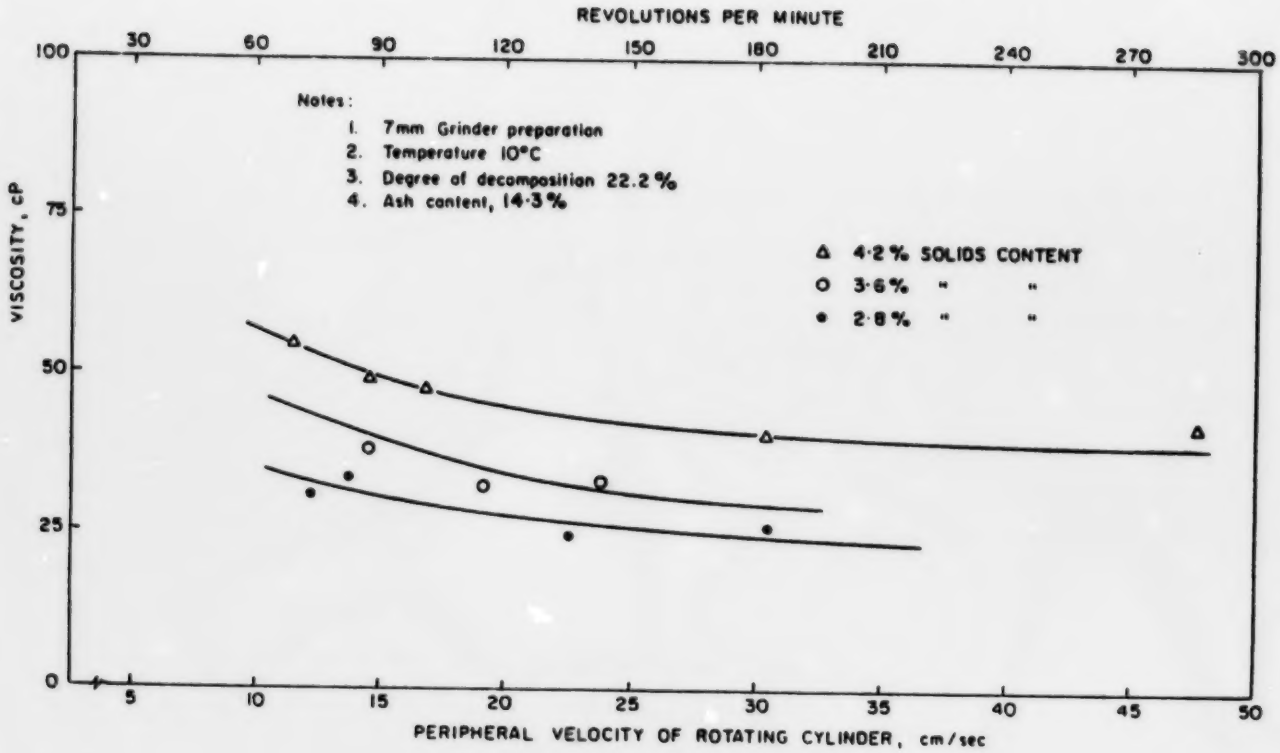


FIGURE 3-14 PEAT SLURRY VISCOSITY CHARACTERISTICS AT DIFFERENT SOLIDS CONTENTS FOR NEW YORK BOG No. 4 (Sample 7, 0 - 3·0 m DEPTH)

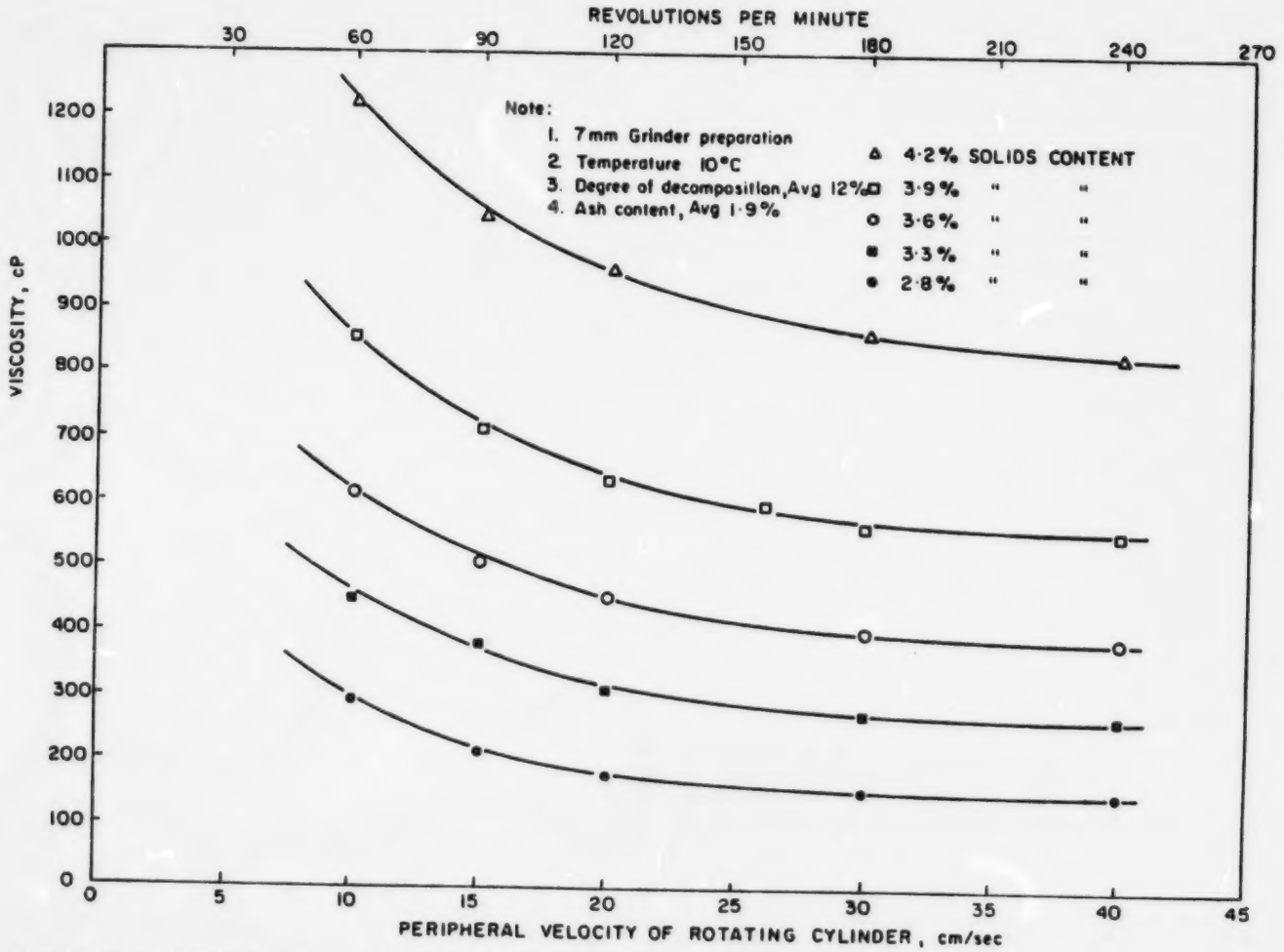


FIGURE 3-15 PEAT SLURRY VISCOSITY CHARACTERISTICS AT DIFFERENT SOLIDS CONTENTS FOR NEW BRUNSWICK PEAT (SAMPLES 1, 3, 4, 5 & 6, 0 – 5·5m DEPTH)

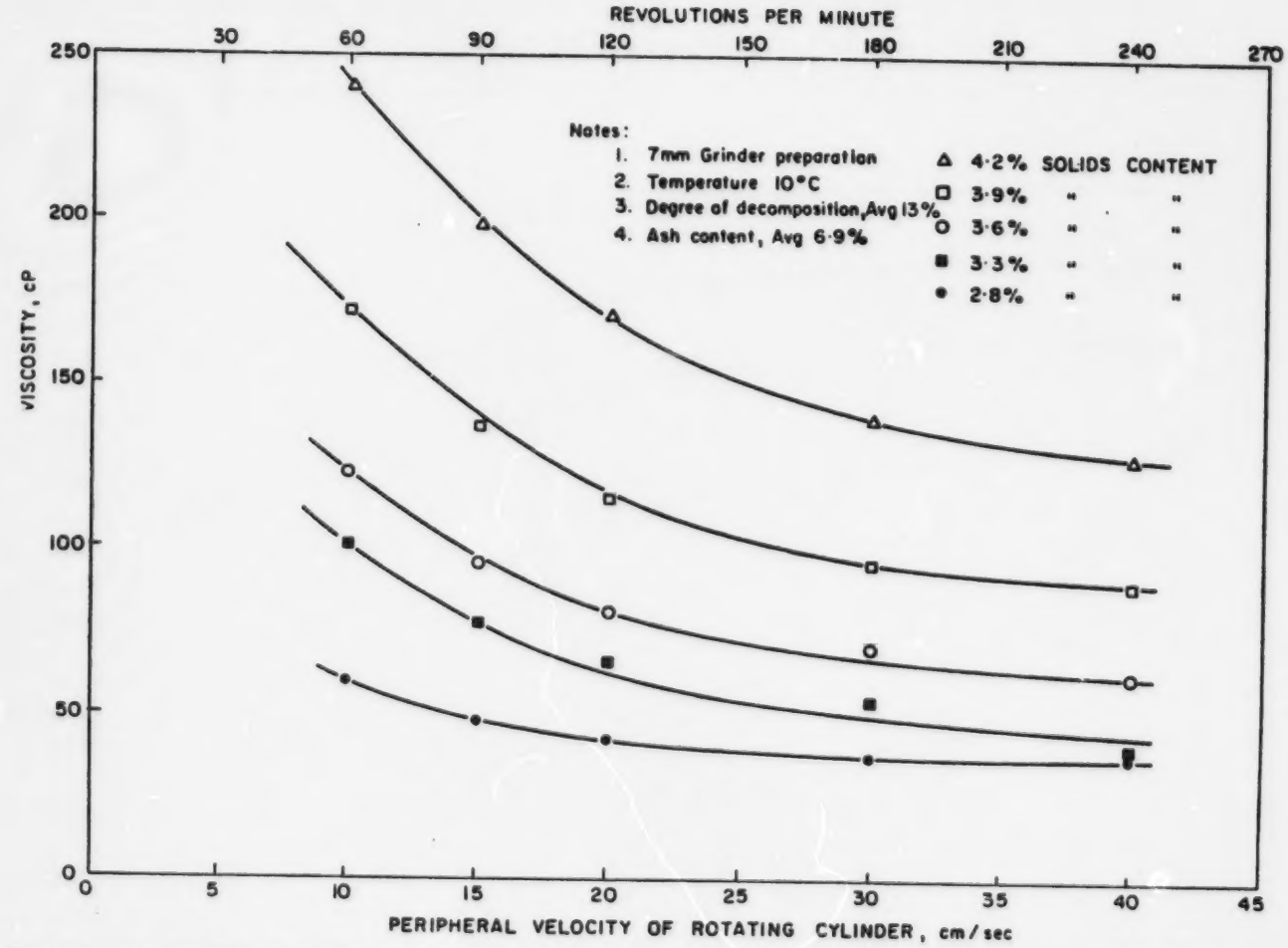


FIGURE 3-16 PEAT SLURRY VISCOSITY CHARACTERISTICS AT DIFFERENT SOLIDS CONTENTS FOR SASKATCHEWAN PEAT (SAMPLES 1, 2 & 3, 0·5 - 2·0m DEPTH)

at a constant speed of the viscometer rotating cylinder, the viscosity increases with increasing solids content.

The Thomas-Stormer viscometer was also used to measure the viscosity of slurries in the 5 to 9% solids content range. Peat from New York Sample No. 6 was used to prepare the slurries. The resulting viscosity values (see Figure 3-17) were compared to Russian values for a similar peat type and compared favourably. This comparison is shown in Table 3-7.

In Figure 3-18, the viscosities of various peat slurries are plotted against solids content for different types of peat at the same speed of the rotating cylinder (15 cm/sec or 90 rpm for the Thomas-Stormer viscometer). They show that the New Brunswick peat samples (highmoor peatland) has the highest viscosity and the New York State peat samples (lowmoor peatlands) have the lowest viscosities. The Ontario peat (transitional moor/lowmoor peatland) have viscosity values between the New Brunswick and New York State values. All the viscosity results demonstrated the increase in viscosity with increased solids concentration.

336 CORRELATION OF THE NORTH AMERICAN AND THE USSR PEAT SLURRY VISCOSITY VALUES

The peat slurry viscosity characteristics (viscosity versus solids content) of the USSR types of peat are shown in Figure 3-19(2). The curves are based on industrial data and are representative for different types of peat, degree of decomposition and ash content. In Figure 3-19 the optimal values of solids content of industrial peat slurries as determined from previous USSR experience are plotted as a straight line. The crossing points of the straight line with the curves represent the optimal values of solids content, for a given type of peat, degree of decomposition and ash content, for design of the pumping and pipeline system.

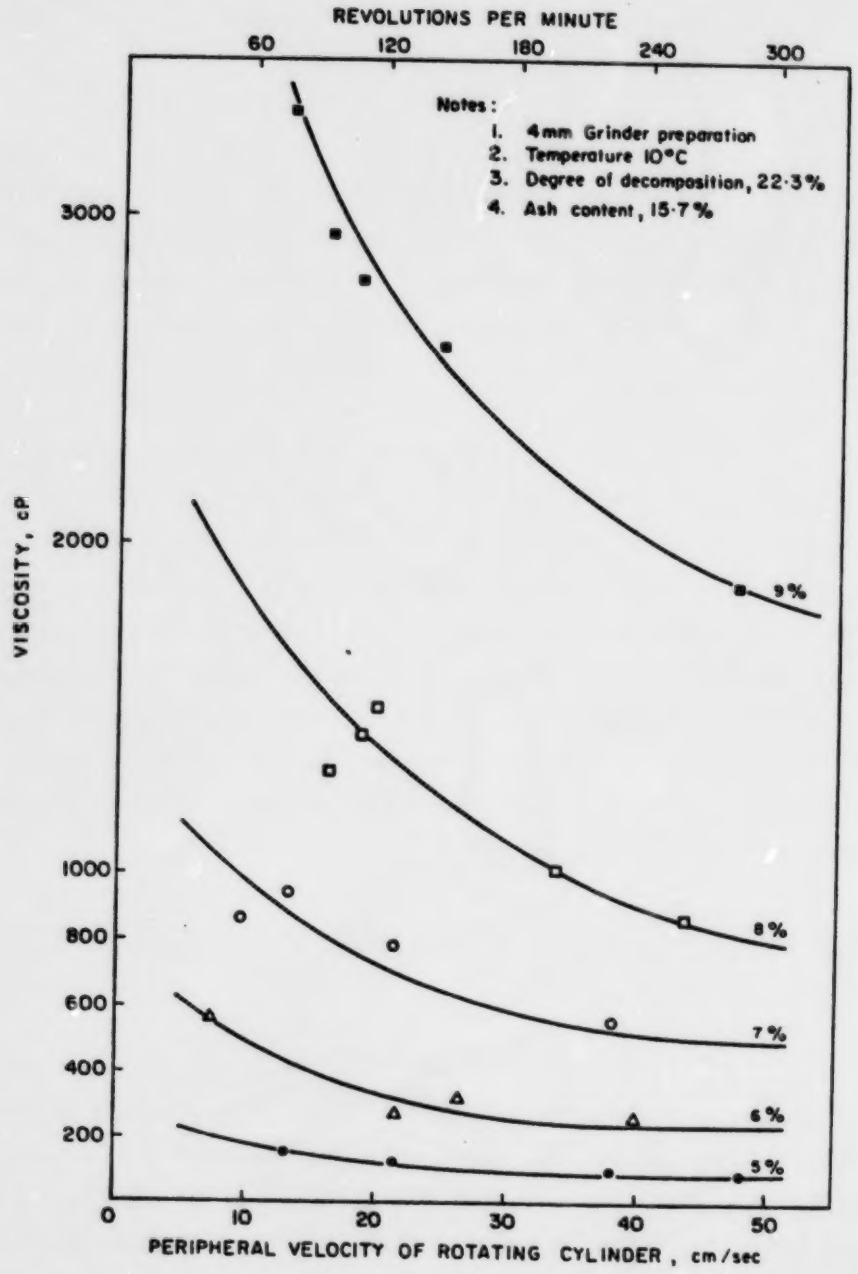


FIGURE 3-17 VISCOSITY OF NEW YORK BOG No. 3 (SAMPLE 6) AT SOLIDS CONTENT 5 - 9% USING THOMAS-STORMER VISCOMETER, 0-3·5M DEPTH

TABLE 3-7

Comparison of Conventional* Viscosity Values for
North American and USSR Lowmoor Peats

	Peat Slurry Solids Content, % by wt.				
	5.0	6.0	7.0	8.0	9.0
North American lowmoor peats (Sample No. 6 of New York Peatland)	135	400	840	1,565	3,120
Russian lowmoor peats (from Figure 3-19)	135	430	1,100	2,000	-

* Determined at 15 cm/sec peripheral velocity of rotating cylinder.

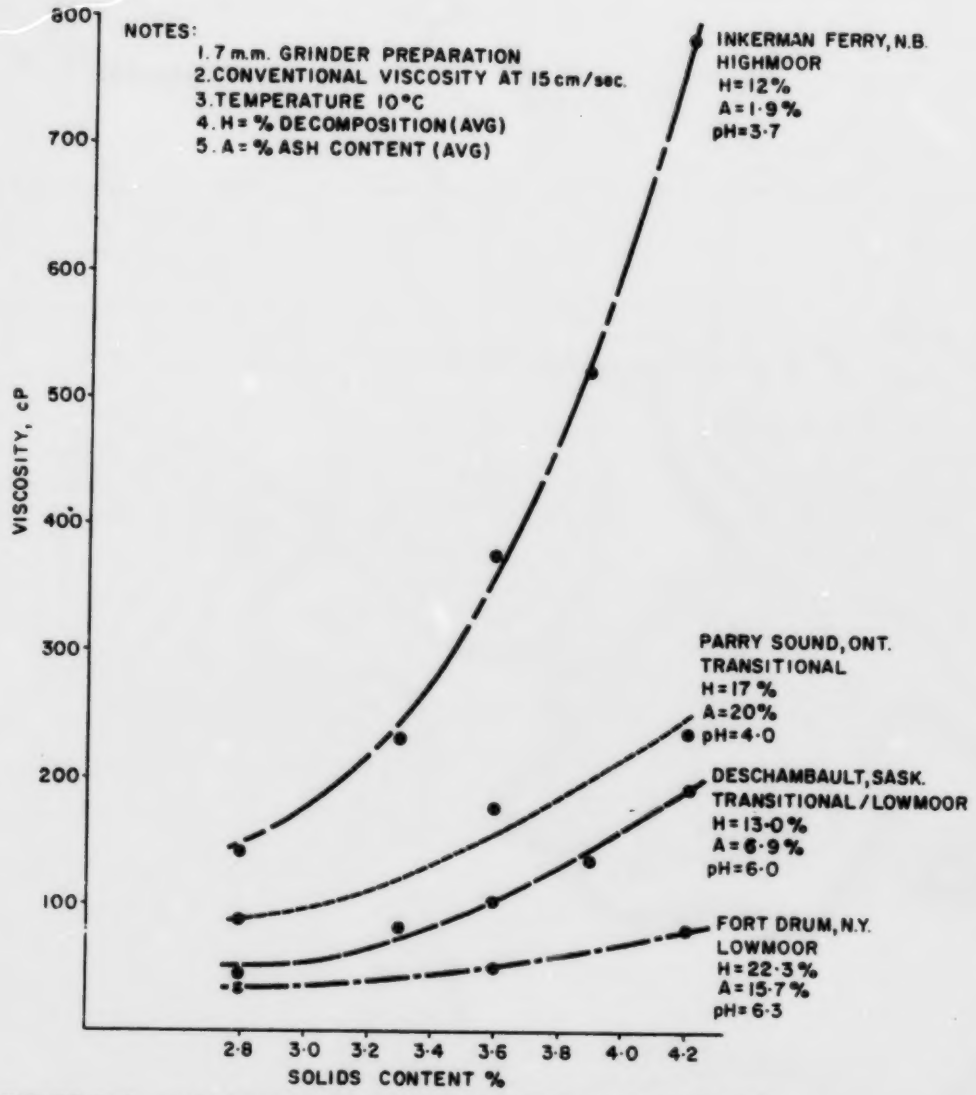


FIGURE 3-18 THE EFFECT OF SOLIDS CONTENT ON PEAT SLURRY VISCOSITY FOR VARIOUS NORTH AMERICAN PEAT TYPES

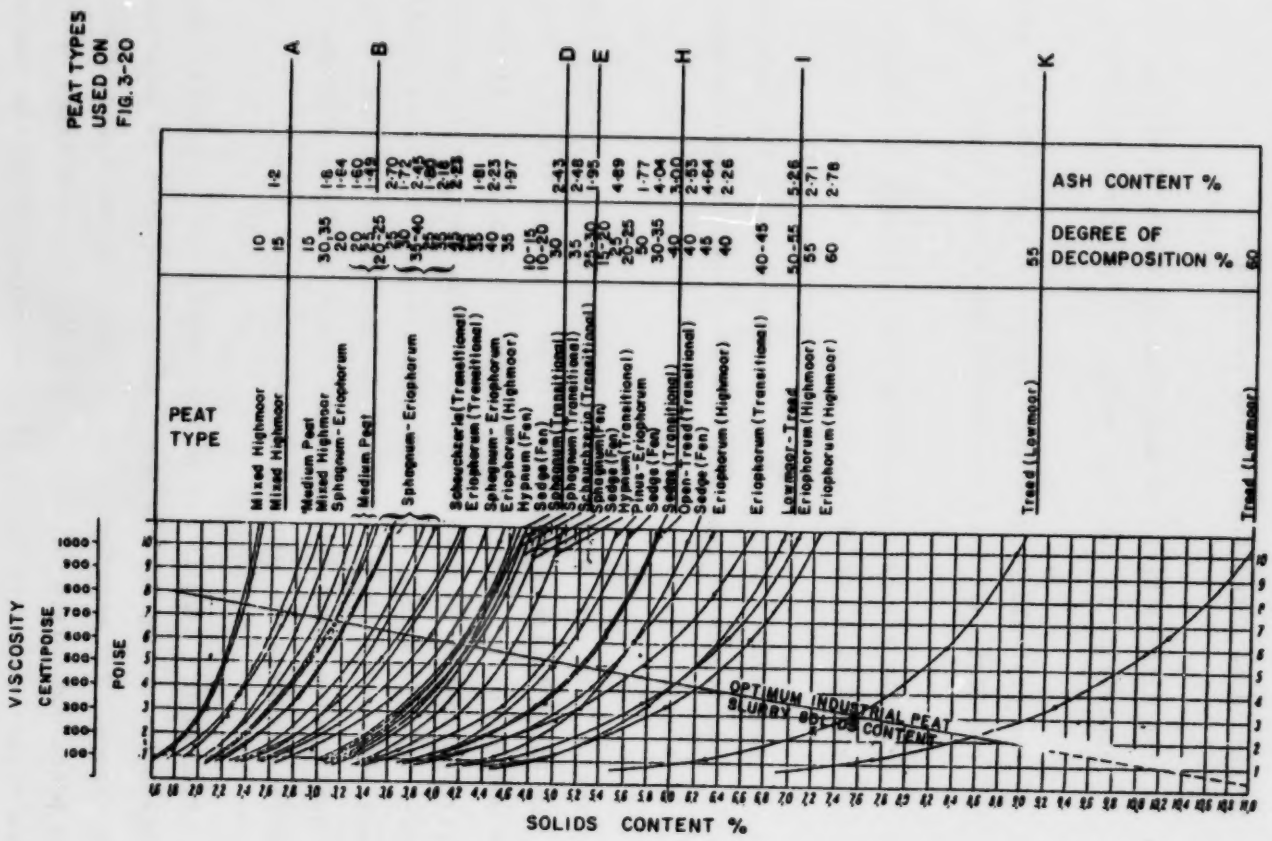


FIGURE 3-19 PEAT SLURRY VISCOSITY VERSUS VARIOUS SOLIDS CONTENT FOR DIFFERENT TYPES OF PEAT, DEGREE OF DECOMPOSITION AND ASH CONTENT (ON THE BASIS OF DATA FROM THE U.S.S.R. ONLY)

Source: GORJACHKIN, V.G., 1955

It should be noted from Figure 3-19 that:

a) the data is based on more than 30 years of mining experience in the USSR using the "hydropeat" method;

b) the peat slurry viscosity curves were obtained by using the Peat Institute viscometer and methodology;

c) all the curves were plotted for a viscometer rotational speed of 15 cm/sec; and

d) peat sample preparation was very close to the industrial conditions of peat slurries (the samples were treated by a grinder).

Taking into account the fact that the viscosity characteristics of the North American types of peat as shown in Figure 3-18 were obtained under similar conditions (viscometer, methods of calculation, laboratory procedures, sample preparation technique), it is possible to compare the curves in Figure 3-19 with the ones in Figure 3-18. This comparison of the USSR and North American types of peat, with similar qualitative characteristics, is shown in Figure 3-20 where the North American curves are plotted against the USSR data.

From Figure 3-20 it may be concluded that the general pattern of the viscosity curves for the North American of peat is analogous to the USSR curves. For example, curve "C" for highmoor types of North American peat, and curves "A" and "B" for the highmoor types of USSR peat show higher viscosity values at given values of solids content (or lower solids content at the constant viscosity values) than curve "J", a North American lowmoor type of peat, or curves "I" or "K", Russian lowmoor types of peat. Analogous trends can be demonstrated for the North American transitional types of peat (curves "F" and "G"), when compared with the USSR transitional peat type (curve "H").

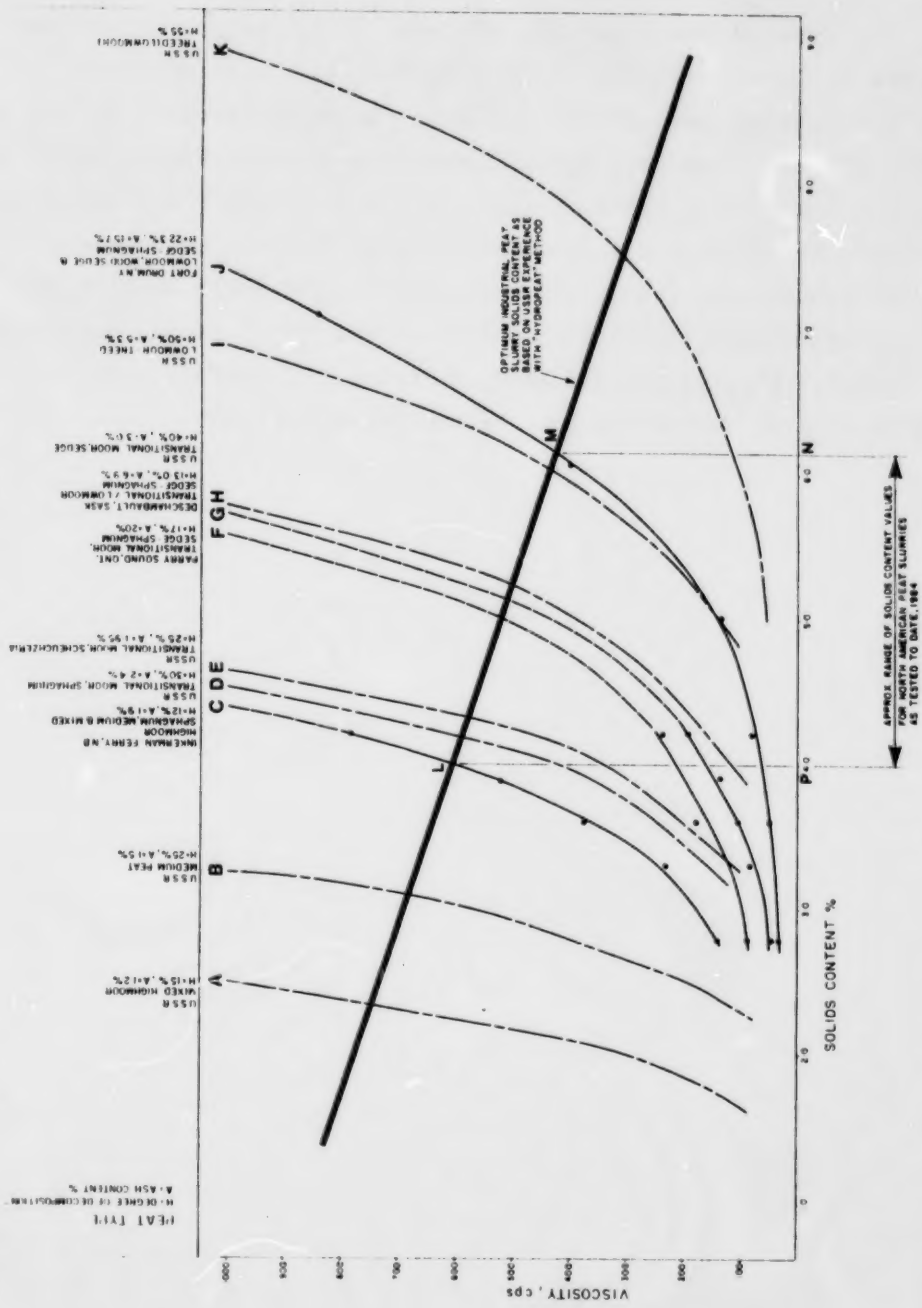


FIGURE 3-20 COMPARISON OF THE RELATIONSHIP BETWEEN PEAT SLURRY VISCOSITY AND SOLIDS CONTENT FOR U.S.S.R. AND NORTH AMERICAN PEAT TYPES

Some of the observable differences in the pattern of the curves in Figure 3-20 can be explained by small variations of humification and ash content values in the North American and the USSR types of peat. However, the differences are insignificant and do not distort the general trend of similarity between the two families of curves. Based on this similarity, a range of expected values of solids content for industrial peat slurries for North American wet mining systems can be anticipated when "hydropeat" mining technology is used. The range is indicated in Figure 3-20 "LMNP", with the solids content values found to be between 4% to 6.2%.

PART 4

PEAT SLURRY PUMPING/TRANSPORT

4.1 INTRODUCTION

It appears, after an extensive search for information for the practical design of hydraulic peat mining systems, that the only available information on the subject is given in the USSR peat mining design handbooks(1,2,10,11). The information is based on numerous model studies the monitoring of existing systems and included statistical data on the relationship between the quality characteristics of various peats and the main peat slurry pumping parameters. The USSR information was developed over a long period (1920's to late 1950's) of large-scale industrial practice, using the "hydro-peat" method described in an earlier Monenco reprot "An Evaluation of Alternative Wet Peat Mining Systems" published by the NRCC in 1983.

Generally, the USSR peat slurry pumping practice using the "hydropeat" method covered solids concentrations ranging from 2 to 6% (solids by weight), depending on the peat characteristics. Since some, although not all, methods of later utilizing peat slurry under study require slurry concentrations higher than 6%, some debate occurred over the usefulness of the Russian information. It is the opinion of the authors that the previous USSR data is quite useful, that the over 40 years of extensive industrial experience in pumping and pipelining peat slurries cannot be ignored and, in fact, can form a basis of knowledge, useful for Canadian peatland conditions, upon which to build possibly better systems and can avoid the common phenomenon of "re-inventing the wheel".

In this part of the report, the peat slurry flow characteristics are discussed and methodologies developed to calculate and predict some of the major pumping parameters. Further, to increase the speed and accuracy of the computations a calculating program was developed by Monenco and is described. It must be pointed out that the work in the USSR was carried out some time ago for specific

equipment. Some of the parameters used for the purpose of development of the tentative calculating methods will require eventual verification through monitoring of the actual systems, both pilot and commercial. A pilot test of a Canadian-built, USSR-style peat slurry pump is currently planned for a New York peatland site, during 1985. Various Monenco and other slurry pumping specialists reviewed in detail many aspects of the Russian calculating methodologies, and although the techniques were considered somewhat "unconventional", it was conceded that the information would be useful, beyond the determination of the main pumping parameters such as viscosity, flow velocity, pump capacity, pipe resistance, dynamic head, etc. which are common to the solution of all slurry pumping problems, since the mothods took into account the dependency of the various slurry characteristics on the peat characteristics (peat type, degree of decomposition, ash content, etc.). As well, a system optimization is made which takes into account both the hydraulic and mining aspects, such as dilution caused by the hydromonitors in breaking down the peat face and required for peat flow to the slurry pump which competes against the need to maintain high slurry concentration for maximum production output. The calculating method includes the pumping characteristic of the "hydropeat" peat slurry pump/macerator, which was specially designed for wet peat mining applications and includes several unique features such as a macerator section and an external pragrell. The pump was operated partly submerged in a peat slurry which included other debris such as lumps of peat, wood remnants, roots, etc.

4.2 WET PEAT MINING CONSIDERATIONS

The Russian penchant for standardization must be kept in mind when evaluating the calculating methods described in this section of the report. In the USSR, basically two standardized peat slurry "hydropeat", mining systems were developed: the "New Standard" mining

system for operations of about 50,000 tpy (33% moisture) air-dried peat and the "Super Standard" system for about 90,000 tpy (33% moisture) air-dried peat capacity. USSR wet mining practice involved standardized mining design criteria, pit configurations, pipe diameters and lengths, slurry pumps, hydromonitors and water and electrical supply systems. Although peat slurry pumps evolved through time, only a few models were in use during a given period, e.g. the last peat slurry mining pump used with the New Standard equipment set (TPD-4A) had a capacity of 500-800 m^3/hr peat slurry and the model used with the Super Standard set (TPD-5) had a capacity of 1200-1600 m^3/hr peat slurry.

The following calculating methods which are described assume that the USSR-model of peat slurry pump/macerator is used. The pump was actually operated in the manner of a combination pump and mining tool, i.e. it was suspended on the end of a crane and lowered into a funnel, created by the cutting action of the water jets (hydromonitors), from where it pumped out accumulated peat slurry. The pump/macerator was moved about during the mining season within a pre-planned "seasonal pit" of standardized geometry, allowing a variation of pipeline length, matched to the pump capacity and production requirements.

Calculation of optimal solids concentration takes into account the basic rheological information on the peat slurry, and also consideration of the in-situ solids content of the peat deposit and the amount of water added through the operation of the water jets. Therefore, the reader will note in the following sections of the report that the pumping and pipelining calculations, of necessity, include mining engineering considerations in their solution.

For practical purposes, experience showed that the pumping/mining technology was limited to a minimum peat thickness of 2 m and a minimum degree of decomposition of 15%.

4.3 PEAT SLURRY FLOW CHARACTERISTICS

In Figure 4-1, the comparison of pressure losses in 755 mm diameter pipeline at various velocities of the peat slurries at different solids contents is shown. It should be noted that the curves shown in Figure 4-1 do not start at the beginning of the ordinate axis and that they tend to cross at increased velocities of the peat slurries. This may be explained by considering the peat slurry elasticity. When insufficient external forces are applied to the peat slurry, only elastic deformations occur. The movement of the peat slurry begins only at the moment when the applied forces exceed a certain limit. The pressure loss values shown in Figure 4-1, at the intersection of the curves and the ordinate axis, correspond to this limit.

The tendency of the curves to cross at increased velocities of the peat slurry indicate that the pressure losses for peat slurries with lower solids content increase faster than for the peat slurries with higher solids content.

Research work done by Professor Yevreinov(10,11) gave interesting results when the characteristics of peat slurry flow were compared to water flow characteristics. At increased velocities, the pressure losses of water flow exceeded similar losses occurring in the peat slurry. The curves plotted for water and peat slurries are shown in Figure 4-1. Professor Yevreinov explains this phenomenon:

> "Generally, turbulent flow conditions for liquid flow in a pipeline is distinguished by two zones, a boundary layer zone and a core flow zone. The boundary layer zone is characterized by the development of eddy currents (as a result of the contact of the stream with the pipe wall) progressing into the centre (core) of the flow. The eddy

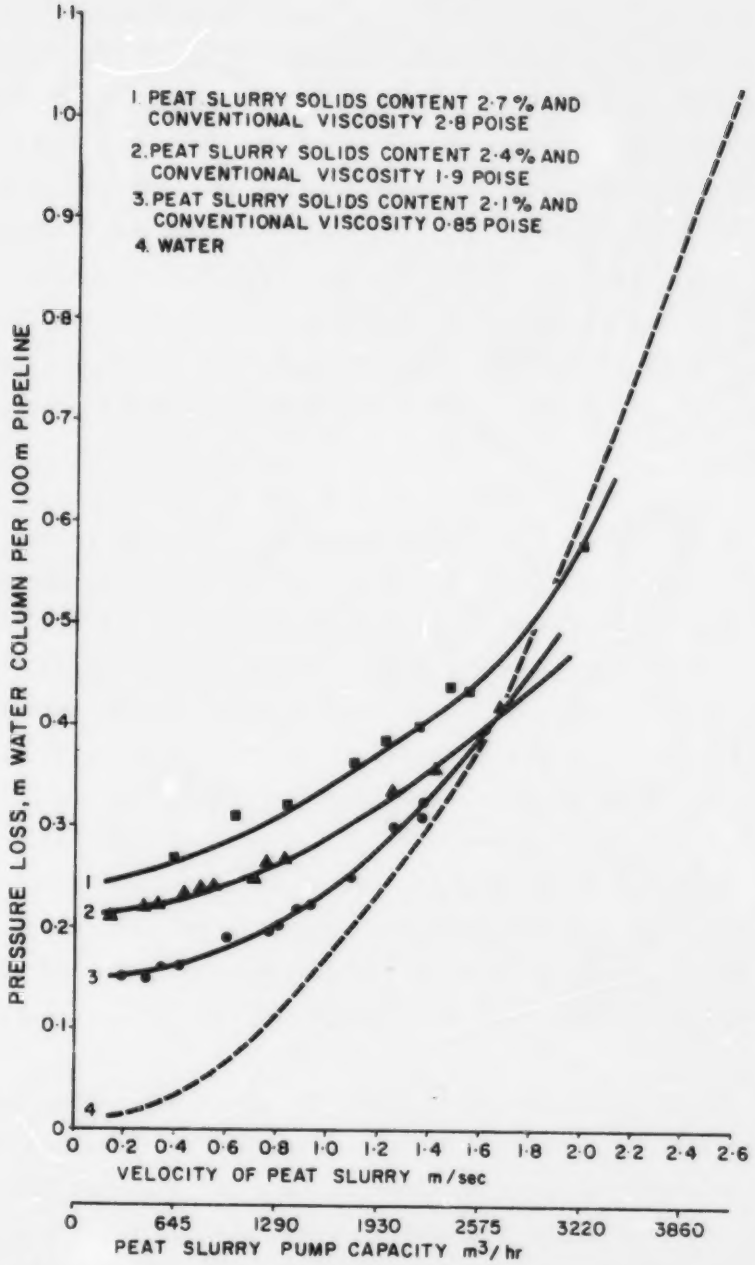

1. PEAT SLURRY SOLIDS CONTENT 2·7% AND CONVENTIONAL VISCOSITY 2·8 POISE
2. PEAT SLURRY SOLIDS CONTENT 2·4% AND CONVENTIONAL VISCOSITY 1·9 POISE
3. PEAT SLURRY SOLIDS CONTENT 2·1% AND CONVENTIONAL VISCOSITY 0·85 POISE
4. WATER
PRESSURE LOSS, m WATER COLUMN PER 100 m PIPELINE
0 0·1 0·2 0·3 0·4 0·5 0·6 0·7 0·8 0·9 1·0 1·1
1
2
3
4
0 0·2 0·4 0·6 0·8 1·0 1·2 1·4 1·6 1·8 2·0 2·2 2·4 2·6
VELOCITY OF PEAT SLURRY m/sec
0 645 1290 1930 2575 3220 3860
PEAT SLURRY PUMP CAPACITY m³/hr

FIGURE 4-1 COMPARISON OF PRESSURE LOSSES FOR 755 mm DIAMETER PIPELINE FOR WATER AND FOR PEAT SLURRIES WITH VARYING SOLIDS CONTENT AND FLOW VELOCITIES

Source: VELLER M.A., 1941

currents are further developed in the core of the flow, in low viscosity liquids, which brings the whole stream into a turbulent condition. Since a peat slurry has a higher viscosity than water, it can be assumed that the eddy currents originating at the boundary layer (at the pipe wall) do not develop further, therefore the whole stream does not develop into a turbulent condition. Consequently, under partial turbulence, the friction losses (for known velocities) will be lower than in water because the flow condition of water is turbulent (causing higher resistance)."

The preceding discussion taken from the USSR literature is mainly of academic interest, and does not really affect the slurry pumping/pipeline system from the design aspect. It is a well known fact that slurries require higher velocities than water to reach turbulent conditions. It is also known that at higher velocities, slurries formed with fibrous materials with a low specific gravity (peat, pulp) can experience lower friction losses than water. Other USSR literature[12,13] explain this occurrence as "initially at lower velocities the presence of inert solids in the medium requires additional energy expenditures; however at higher velocities the light, fibrous particles become very active in structuring the flow, "laminarizing" the flow and "smoothing" the flow wall contact zone."

According to the references, all other parameters being equal, the viscosity of an industrial peat slurry increases with an increase in solids content as shown in Part 3. Also the friction losses of the flowing peat slurry increase with increasing viscosity. For a given pump, increased friction losses mean a reduction in the pumping capacity.

The case is considered when the peat slurry suction pump with capacity "Q"(m^3) pumps the peat slurry with solids content "C_{sl}"(%) through the pipeline "L"(m) long. Assume that the length of the pipeline is reduced. Then, one would think that the pump capacity should increase due to the reduction of the pipeline friction losses at the constant solids content. As observed, however, the following occurs at the suction end of the pump:

a) the pump capacity increases;

b) the flow velocity of the peat slurry approaching the suction end of the pump in the mining pit also increases; and

c) the solids content in the peat slurry will increase up to a certain point; the solids content increase will cease when the peat slurry fluidity in the mining pit reaches the edge of its plasticity limit.

Thus, the phenomenon of solids content increase caused by the reduction of the pipeline length may be observed in the mining pit as long as the peat slurry fluidity is sufficient to keep peat slurry flowing into the pump suction end. Beyond a certain point, a further reduction of the pipeline length will not affect the peat slurry solids content (which remains constant from that point). This pipeline length is called the "critical length" in the original USSR definition, however it is considered to be on outcome of critical resistance.

According to our (Monenco's) analysis of the situation, the entire hydraulic concept presented herein is based on the acceptance of the phenomenon occurring during hydraulic mining and transporting of peat through a pipeline longer than some "critical length". The phenomenon, which according to the reference, has been observed in

practice, lies in the fact that the peat slurry flow rate stays unchanged for various pipe lengths as long as the pipe is longer than some critical length. The critical length is adopted from the reference to be approximately 1000 m.

It is considered that such a "critical length" will not be universal for all pump-pipe systems but must be determined for a given system arrangement. The phenomenon is explained to be caused by the effect from the approaching conditions at the pump suction side on the slurry concentration and thus viscosity which, in turn, is the factor affecting the system hydraulic resistance. The ultimate unchanged hydraulic resistance results in the constant total dynamic head on the pump and, thus, in constant flow rate. The hydraulic regime at the suction side which appears to be the key factor for the phenomenon, is an outcome of the pump-pipe interaction and the intake arrangement and therefore, is system-specific. It is not improbable that a substantially different system may have a different "critical length". A potential concern is that if such a "critical length" is substantially longer than 1000 m, the methodology may not be applicable within the range of the pipe lengths considered.

Based on the observations of previous USSR practice, it can be assumed that the solids content of a given peat slurry can increase only up to a certain threshold level and at this point the optimum pump yield is reached. The optimum pump yield is measured in terms of tonnes of dried peat per hour. The optimum pump yield "P" per hour is determined by the following equation:

$$P = Q \times Y \times \frac{C_{sl}}{100-Wdp} \qquad (4-1)$$

where: P = optimum pump yield (tonnes dried peat per hour);
Q = theoretical pump capacity (in m^3) of peat slurry per hour;
Y = the peat slurry volume weight, assumed to be equal 1.0;
C_{sl} = peat slurry solids content (%); and
W_{dp} = moisture content of dried peat, %.

4.4 METHODS OF CALCULATING THE OPTIMAL PEAT SLURRY SOLIDS CONTENT, PUMP CAPACITY AND PUMPING DISTANCE

441 CALCULATING METHODS

The calculating methods to determine optimal peat slurry solids content, pump capacity and pumping distance include two graphic analytical methods (described later as method "A" and method "B") and a peat "botanical spectrum" method(12). Method "A" is generally used for designing the peat slurry suction pump/pipeline system, i.e., it is used when the system slurry capacity is known and the correlation between slurry concentration and pipeline length has to be developed for this optimization. Method "B" is used for designing a new pump/macerator to harvest a given amount of peat, i.e., it is used when the pipeline length is known and the correlation between slurry concentration and system capacity has to be developed for their optimization.

Both methods are used for the analysis of the system operating within the hydraulic regime described earlier, when constant slurry flow occurs for various pipe lengths, beyond a certain critical length. Use of the peat deposit botanical spectrum method is limited to the determination of peat slurry solids content only.

The graphic-analytical methods are based on the phenomenon, which is also observed in practice, that the peat slurry pumping rate stays almost constant when the pipeline length "L" is varied beyond the "critical" value (all other parameters being constant) and only the peat slurry solids content "C_{sl}" varies. This inversely proportional dependence between "L" and "C_{sl}" (i.e., length increases, solids concentration decreases) was demonstrated in industrial practice in the USSR.

.1 Graphic-Analytical Method "A"

Method "A" is used when the peat slurry pump curves are available, e.g., pump performance curve (Q versus H) corrected for peat slurry, with a solids concentration equal or close to that recommended as optimal for the given peat, see Figure 3-19. As well, the peat slurry viscosity information from laboratory testing on peat samples at different solids content are required.

A typical peat slurry pump performance curve is shown in Figure 4-2. An example peat slurry viscosity characteristics from laboratory tests are shown in Figure 4-3. A pumping rate of "Q" for the given pump, and a pipeline inside diameter of "D" is known based on the previous experience. Four different pipeline lengths "l" are assumed for the iterative calculating technique used.

The average velocity (m/s) of the peat slurry is determined as:

$$V = \frac{4 \times Q}{3600 \times \P \times D^2} \qquad (4\text{-}2)$$

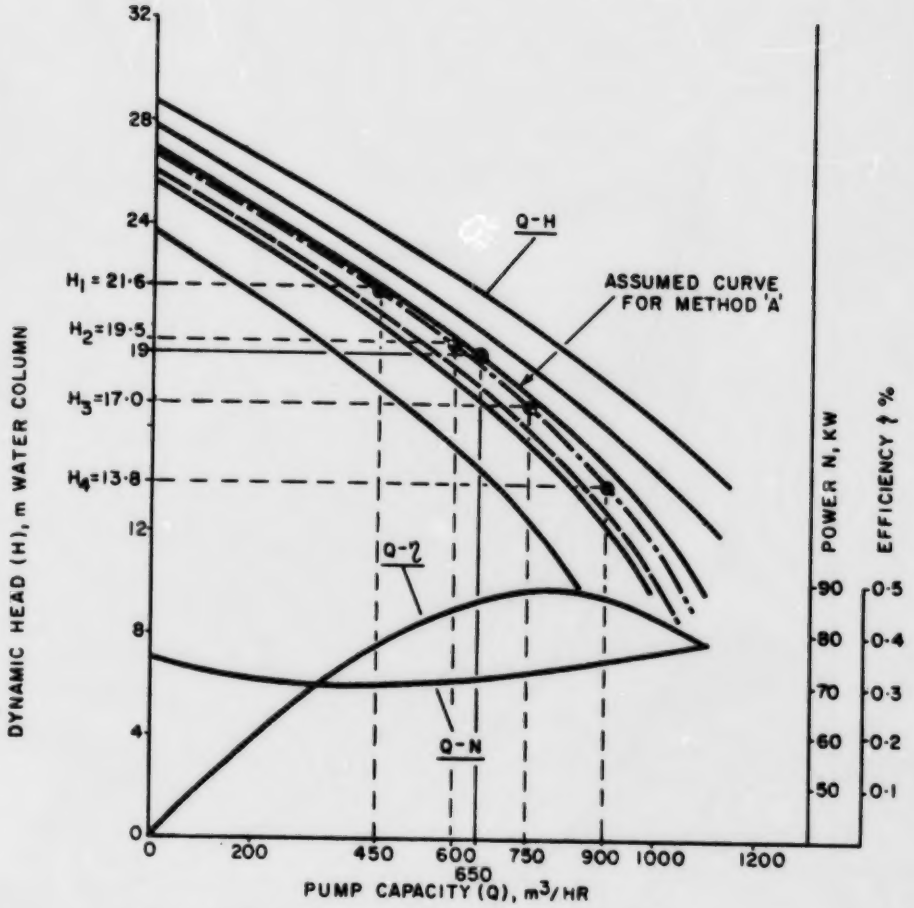


FIGURE 4-2 PUMP (MODEL TPD-4A) PERFORMANCE CHARACTERISTICS FOR PEAT SLURRIES AND WATER

LEGEND:

——— PUMP PERFORMANCE CURVES FOR PEAT SLURRIES WITH VARIOUS SOLID CONCENTRATIONS

— — — PUMP PERFORMANCE CURVE FOR WATER

—·—·— ASSUMED CURVE FOR PEAT SLURRY FOR METHOD 'B' (BASED ON WATER PERFORMANCE CURVE)

Source: PEAT ENGINEERS HANDBOOK, MOSCOW, 1944

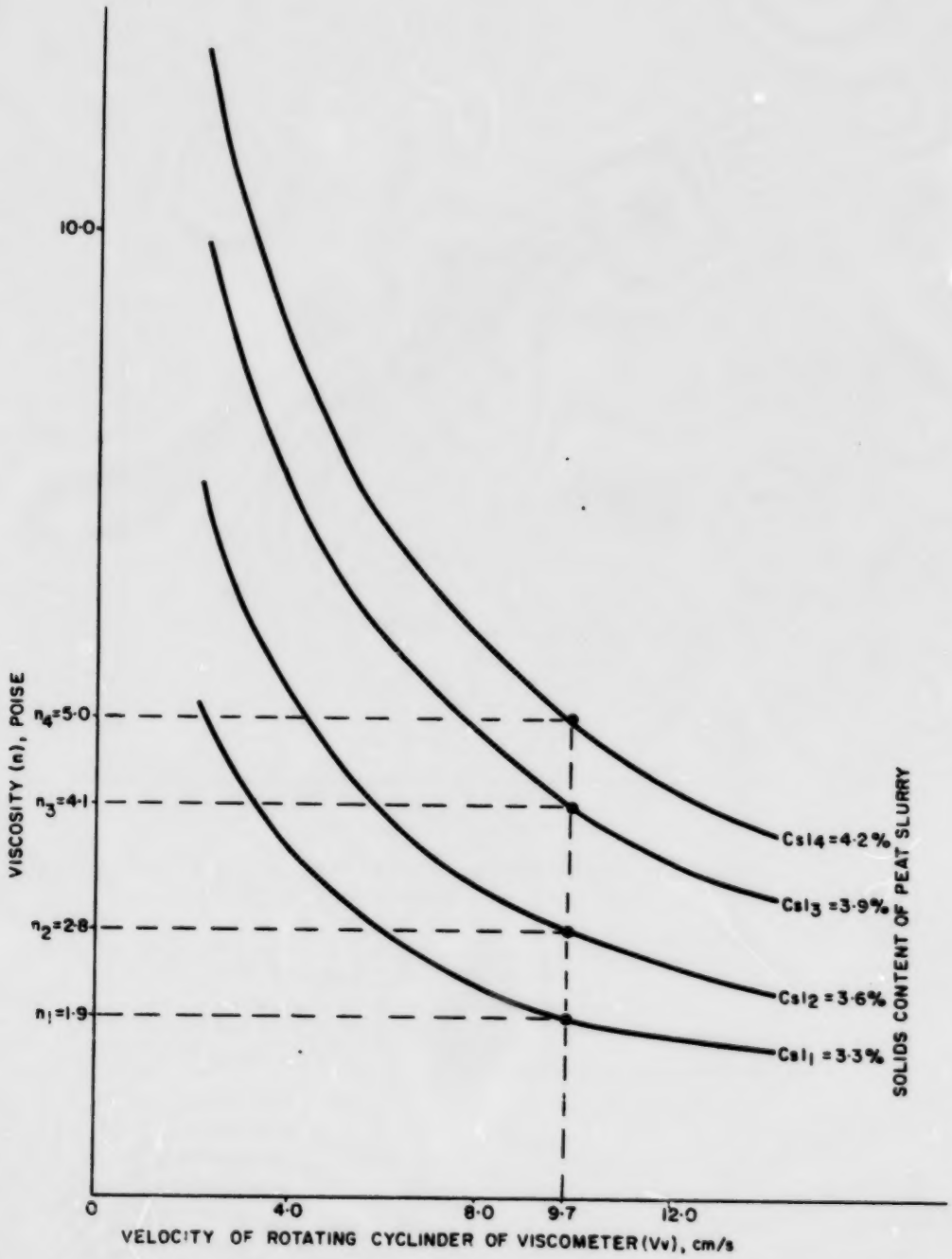


FIGURE 4-3 LABORATORY PEAT SLURRY VISCOSITY CHARACTERISTICS

Source: PEAT ENGINEERS HANDBOOK, MOSCOW, 1944

It is assumed that the pressure head at the discharge end of the pipeline is atmospheric and static head is zero, then the pressure loss in the pipeline is equal to the pump head "H"(m), which is determined from the pump performance curve. If the static head is not zero then the pressure loss in the pipeline will be equal to the difference between the available dynamic head and the static head.

Applying the D'Arcy-Weisbach equation as generally used for pipe flow calculations, the peat slurry friction factor "f" can be calculated:

$$H = f \times \frac{l \times V^2}{D \times 2g} \qquad (4\text{-}3)$$

where: H = pump loss (m);
l = pipeline length (m); and
g = gravitational constant (9.81 m/s).

Rearranging, we obtain:

$$f = \frac{H \times D \times 2g}{l \times V^2} \qquad (4\text{-}4)$$

For the four assumed values of "l", we obtain four values of "f".

As a result of many years of industrial experience, empirical equations for the peat slurry friction factor "f" have been developed. The coefficient "f" is dependent on the following parameters:

- type of peat and its degree of decomposition;
- solids content;
- velocity of the peat slurry;

- pipeline diameter; and

- peat slurry temperature.

The Peat Technology Institute (USSR) developed the following empirical equation (6) based on the experimental data for pipeline diameters ranging from 0.57 to 0.75 m for conventional steel pipelines. More data should be collected for other pipe sizes and materials to confirm the following formula:

$$f = \frac{0.16 \times n}{V_v \times D^2} \qquad (4\text{-}5)$$

where: 0.16 = an empirical constant;
n = peat slurry viscosity (poise); and
V_v = velocity of rotating cylinder of the viscometer (cm/s).

The velocity of the rotating cylinder is determined according to the following empirical equation based on the experimental data (6):

$$V_v = 8.1 \times V \qquad (4\text{-}6)$$

where: 8.1 = an empirical constant.

From this point, the further calculation procedures are best illustrated by following an example. For instance, it is assumed that the following initial data are available for the calculations:

- the peat slurry suction pump performance characteristics and conventional viscosities of the peat slurry as described earlier (see Figures 4-2 and 4-3);

- assume a required peat slurry pump capacity, Q = 650 m^3/hr; and

- assume the pipeline internal diameter, D = 0.438 m (or 18").

The following next few steps in the calculation are directed towards determination of the optimal solids content.

The average peat slurry pipeline flow velocity can be determined using equation 4-2 as:

$$V = \frac{4 \times Q}{3600 \times \P \times D^2} = \frac{4 \times 650}{3600 \times 3.14 \times 0.438^2} = 1.2 \text{ m/s}$$

The velocity of rotating cylinder of the viscometer can be determined using equation 4-6:

$$V_V = 8.1 \times V = 8.1 \times 1.2 = 9.7 \text{ cm/s}$$

For the calculated V_V = 9.7 cm/s, four values of conventional viscosity can be determined from the viscosity curves shown in Figure 4-3, e.g., n_1 = 1.9; n_2 = 2.8; n_3 = 4.1; n_4 = 5.0. The four curves were obtained during lab tests with the viscometer for the peat deposit samples using peat slurries of different solids content: e.g., Csl_1 = 3.3%; Csl_2 = 3.6%; Csl_3 = 3.9%; Csl_4 = 4.2%.

The four values of solids concentration were selected since it is expected they will cover the range where the optimal solids content will be found. From Figure 4-3, using V_V = 9.7 cm/s four values of viscosity (n) corresponding to the four levels of solids concentration and this information is used to construct the new Figure 4-4 which is used later when new values of viscosity are determined using the empirical equation (4-5) for the pump/pipeline conditions shown. The viscosity and solids content values for the construction of Figure 4-4 are presented in Table 4-1.

TABLE 4-1

Viscosity Versus Solids Content
(as taken from Figure 4-4)

Number of Point	Viscosity (poise)	Solids Content of Peat Slurry (%)
1	$n_1 = 1.9$	$Csl_1 = 3.3$
2	$n_2 = 2.8$	$Csl_2 = 3.6$
3	$n_3 = 4.1$	$Csl_3 = 3.9$
4	$n_4 = 5.0$	$Csl_4 = 4.2$

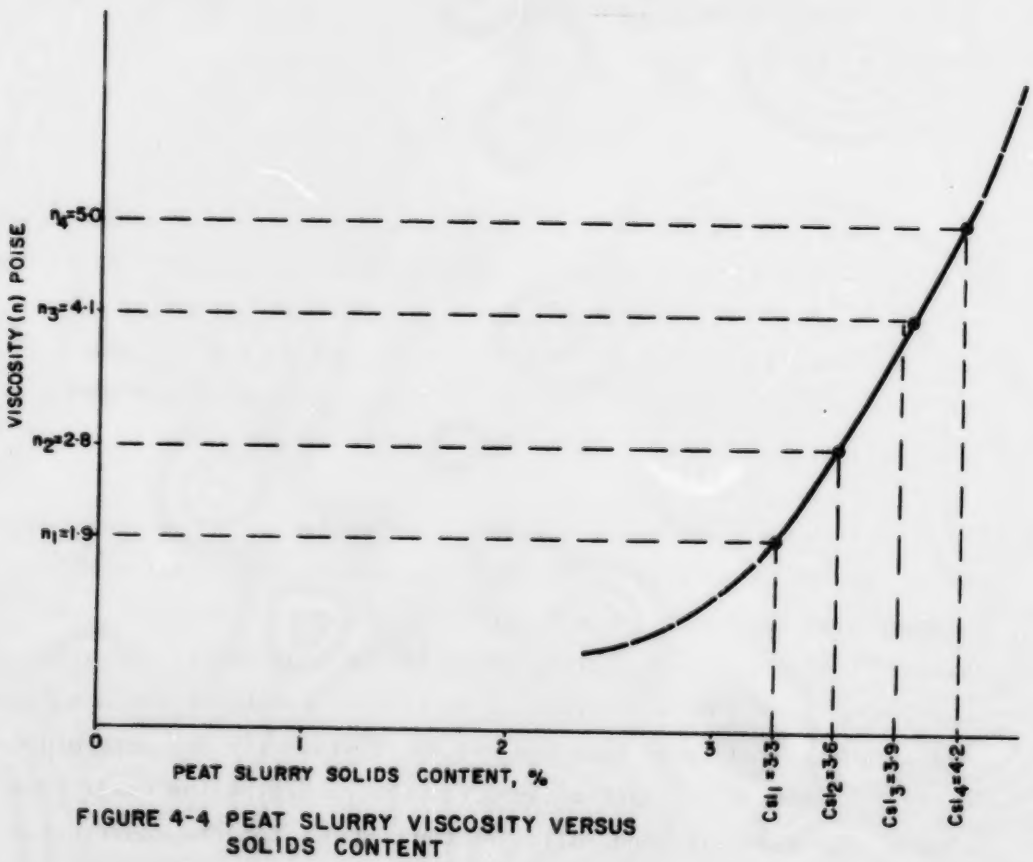


FIGURE 4-4 PEAT SLURRY VISCOSITY VERSUS SOLIDS CONTENT

The pressure loss in the pipeline is determined from the selected pump performance curve for peat slurries "Q-H" (Figure 4-2). For the given Q = 650 m^3/hr, the pressure loss (H) is equal to 19 m of water column.

To obtain the peat slurry resistance coefficient, we assume four different values of pipeline length; e.g.

l_1 = 850 m; l_2 = 950 m; l_3 = 1050 m; l_4 = 1150 m.

Using the D'Arcy-Weisbach equation (4-4) the four friction factors f_1; f_2; f_3; f_4 corresponding to l_1; l_2; l_3; l_4 are calculated:

$$f_1 = \frac{H \times D \times 2g}{l_1 \times V^2} = \frac{19 \times 0.438 \times 2 \times 9.81}{850 \times 1.2^2} = 0.1334$$

f_2 = 0.1194

f_3 = 0.108, and

f_4 = 0.0986.

The values of f_1; f_2; f_3; f_4 are used in the empirical formula 4-8 and, solving for "n" as the unknown variable, four new viscosity values n_1; n_2; n_3; n_4 are calculated:

$$n_1 = \frac{f_1 \times V_v \times D^2}{0.16} = \frac{0.1334 \times 9.7 \times 0.438^2}{0.16} = 1.6$$

n_2 = 1.4;

n_3 = 1.3; and

n_4 = 1.15.

For the calculated values of conventional viscosity n_1 = 1.6, n_2 = 1.4, n_3 = 1.3, n_4 = 1.15, four new values C_{s1}[1]; C_{s1}[2]; C_{s1}[3]; C_{s1}[4] for the solids content of the peat slurry are determined from the graph in Figure 4-5 (for purposes of clarity in reading the graph, the

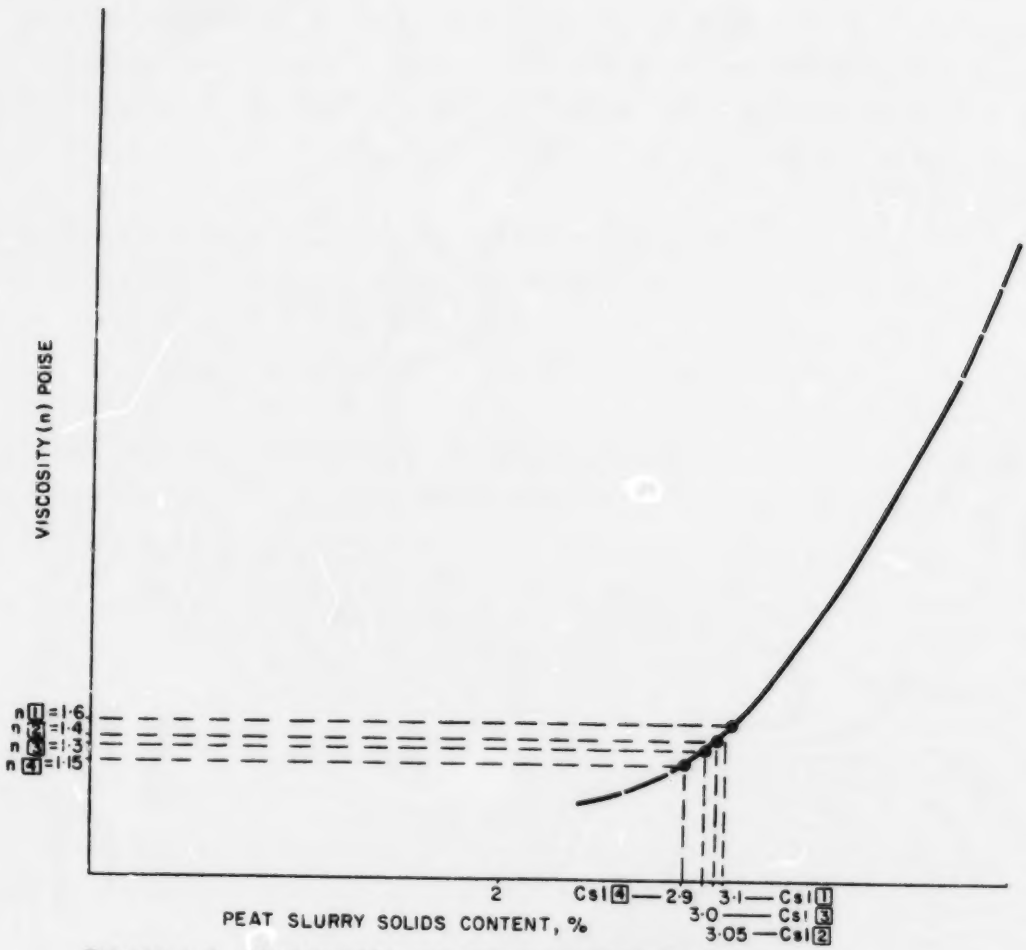


FIGURE 4-5 CALCULATED VALUES OF VISCOSITY VERSUS PEAT SLURRY SOLIDS CONTENT

curve n vs. C_{sl} in Figure 4-4 was transferred without change to Figure 4-5). Thus, for the assumed values l_1, l_2, l_3, l_4 of the pipeline length, the corresponding parameters $C_{sl}[1] = 3.1\%$; $C_{sl}[2] = 3.05\%$; $C_{sl}[3] = 3.0\%$; $C_{sl}[4] = 2.9\%$ for the peat slurry solids content, are determined.

The preceding calculations determined "optimal solids concentrations" for the assumed lengths of slurry pipelines and slurry conditions. The following steps are for the purpose of determining the actual design length of the pipeline for an assumed mining pit geometry. In the course of this calculation, the optimal solids concentration for the actual design length will be determined and the amount of water addition required (mining by water-jet) to prepare the peat slurry.

In the USSR source, the "optimal" solids concentration for a given peat is defined as: "solids content which provides maximum capacity of the system in terms of the peat output for the given time span." It follows from the methodology presented that there are two opposing factors involved in the process of maximizing the peat output for the given pumping system capacity: slurry concentration calling for shortest pipeline and mining pit size calling for longest pipeline. Satisfaction of both conditions, i.e., compatibility between concentration - pipe length - pit size, gives the solution to the problem with the optimal solids concentration as an outcome of the determined pipe length. A shorter pipe, although it would increase concentration, would require a smaller mining pit, finally reducing the total peat output; a longer pipe would lead to the same result since although allowing larger pit, would cause a reduction in slurry concentration.

The method of calculating the pipeline design length is based on the traditional wet peat mining arrangement with the slurry pipe bent towards the reservoir as shown in Figure 4-6. The direction of

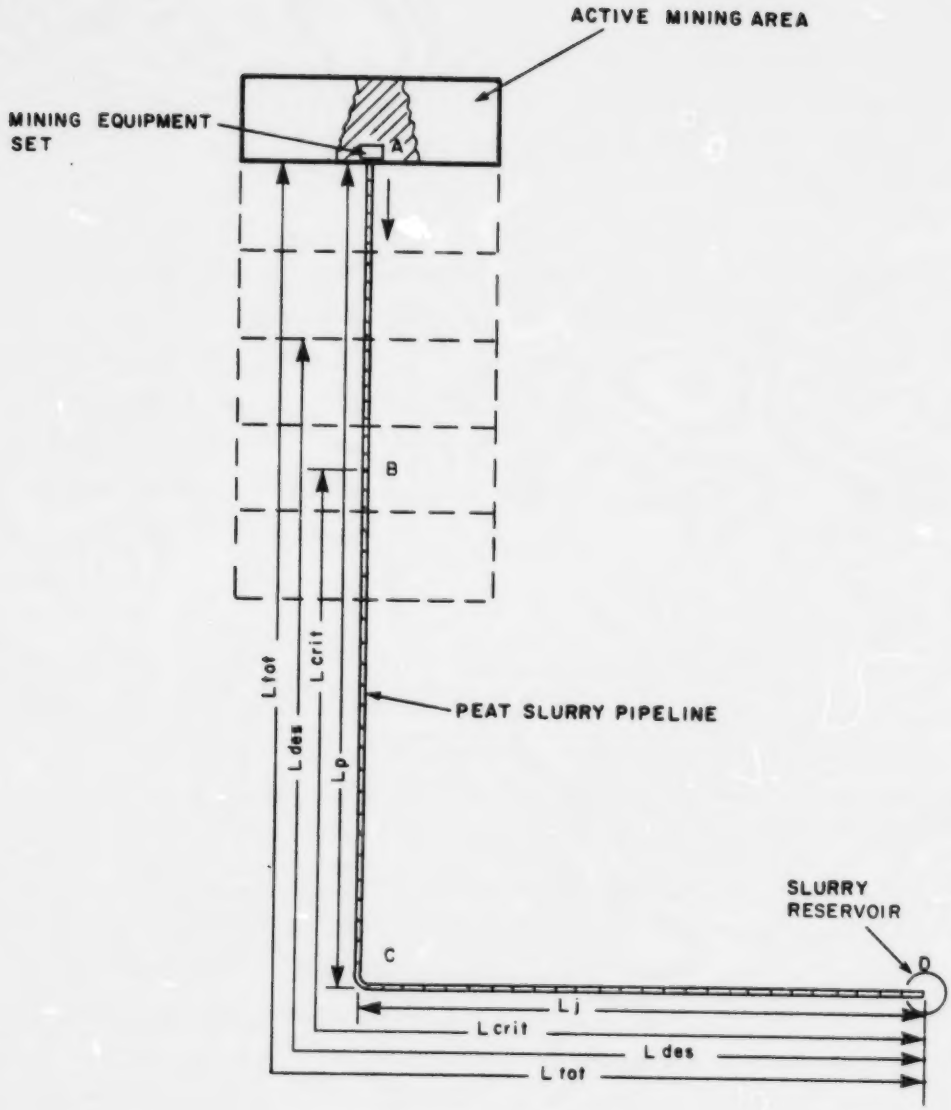


FIGURE 4-6 SCHEMATIC CONFIGURATION OF THE MINING PIT AREA FOR DETERMINATION OF THE PIPELINE DESIGN LENGTH

Source: PEAT ENGINEERS HANDBOOK, MOSCOW, 1944

the mining operations is from point "A" (location of slurry pump) to point "D" (reservoir). The total pipeline length (L_{tot}) from the peat slurry suction pump to the reservoir (section A-D) consists of the length of the seasonal pit, "L_p", (length of section A-C) and the length of "L_j" of the pipeline joining the latter to the collecting reservoir (section C-D).

$$L_{tot} = L_p + L_j \qquad (4\text{-}7)$$

In the graphic-analytical method of calculation used in the USSR, and based on industrial experience with different pump capacities and pipeline diameters, the critical length "L_{crit}" is usually assigned the value of approximately 1000 m (for the pipeline diameter considered in the example, it is estimated to be somewhat less; assume 850 m). The assumed critical length is shown in Figure 4-6 as section B-D. Hence, the length, $L_p + L_j - L_{crit}$, is that part of the pipeline where the change in the solids content of the peat slurry may occur (this part is shown as section A-B).

Assuming that the solids content is minimal (for mining configuration shown) with the pump at point "A" of the section A-B, and that it is maximum with the pump. At point "B", the average solids content will take place at the distance:

$$\frac{L_p + L_j - L_{crit}}{2} \qquad (4\text{-}8)$$

Note that the change in solids concentration occurs not in different sections of the pipeline but at different points in time with different locations of the pump and thus different pipeline lengths, in turn causing the change in slurry concentration.

The total design length of the pipeline will then be:

$$L_{des} = \frac{(L_p + L_j - L_{crit})}{2} + L_{crit} = \frac{L_p + L_j + L_{crit}}{2} \qquad (4\text{-}9)$$

The length "L_j" is easily found depending on the mining plan and the number of equipment sets. Therefore, to calculate "L_{des}", only "L_p" has to be determined.

Method of Calculation of "L_p"

a) If the width of each seasonal pit is "B" (in m), as shown in Figure 4-6, and the average depth of the seasonal pit is "h" (in m), then the volume of the seasonal pit "Z_p" (in m^3) may be calculated as:

$$Z_p = L_p \times B \times (h-0.3) \times \beta \qquad (4\text{-}10)$$

where: 0.3 = the suggested thickness of the bottom layer of the peat deposit left for future reclamation, in m;

β = the utilization factor of the peat deposit (related to the various types of losses during mining operations but not including losses related to the bottom layer 0.3 m).

b) On the other hand, at the seasonal capacity of the peat slurry pump, Q_{seas} (in m^3), the same volume of the peat deposit "Z_p" may be determined as:

$$Z_p = \frac{Q_{seas}}{Y \times (1+W)} \qquad (4\text{-}11)$$

where: Q_{seas} = the seasonal peat slurry pump capacity;
Y = the peat slurry volume weight assumed to be equal 1.0; and
W = the water addition coefficient to be described later.

c) The seasonal capacity of the peat slurry pump is calculated according to the following formula;

$$Q_{seas} = Q \times T \times N \times K \qquad (4\text{-}12)$$

where: Q = the peat slurry suction pump capacity, in m^3/hour;
T = number of working hours per day;
N = number of working days per season; and
K = the utilization factor for the pump.

d) From equations 4-10 and 4-11, "L_p" (in m) is determined by:

$$L_p = \frac{Q_{seas}}{(1+W) \times B \times (h-0.3) \times \beta} \qquad (4\text{-}13)$$

e) If, "Z_r" (in m^3) is the volume of the raw peat deposit, "y_r" (in tonnes/m^3) is the volume weight of 1 m^3 of raw peat, and "C_r" (in %) is the solids content of the raw peat deposit, then the overall weight "G_r" (in tonnes) of the dry solids (i.e., moisture content equals zero) in the raw peat deposit will be:

$$G_r = \frac{Z_r \times y_r \times C_r}{100} \qquad (4\text{-}14)$$

f) On the other hand, if "Z_{sl}" (in m^3) is the overall volume of the peat slurry obtained by water-jet mining of the raw peat deposit, "y_{sl}" (in tonnes/m^3) is the volume weight of the peat slurry, and "C_{sl}" (in %) is the solids content of the peat slurry, then the overall weight "G_{sl}" of the dry solids in the peat slurry will be:

$$G_{sl} = \frac{Z_{sl} \times y_{sl} \times C_{sl}}{100} \qquad (4\text{-}15)$$

Taking into account, that

$$G_r = G_{sl}$$

the following equation results:

$$Z_{sl} \times y_{sl} = \frac{Z_r \times y_r \times C_r}{C_{sl}} \qquad (4\text{-}16)$$

g) The weight of the water addition is equal to the peat slurry overall weight minus the weight of the raw peat deposit, i.e.,

$$Z_{sl} \times y_{sl} - Z_r \times y_r = \frac{Z_r \times y_r \times C_r}{C_{sl}} - Z_r \times y_r =$$

$$= \frac{Z_r \times y_r \times (C_r - C_{sl})}{(C_{sl})}$$

The water addition coefficient "W" is the ratio of the weight of the water added to the raw peat deposit, to the weight of raw peat in the deposit. Then, the water addition coefficient "W" can be determined as:

$$W = \frac{\frac{Z_r \times y_r \times (C_r - C_{s1})}{(C_{s1})}}{Z_r \times y_r} = \frac{C_r - C_{s1}}{C_{s1}} \qquad (4\text{-}17)$$

h) Assuming "C_r" (solids content of the raw peat deposit) = 11%, four values W_1, W_2, W_3, W_4 of water addition coefficients are calculated using equation (4-17) for the different values of C_{s1}[1], C_{s1}[2], C_{s1}[3], C_{s1}[4] as determined earlier.

$$W_1 = \frac{C_r - C_{s1}[1]}{C_{s1}[1]} = \frac{11.0-3.1}{3.1} = 2.5$$

$W_2 = 2.6$

$W_3 = 2.7$

$W_4 = 2.8$

The values of the water addition coefficient "W" generally vary within limits between 1.5 and 2.5 depending on the degree of decomposition of different types of peat and the ash content of the peat deposit (sometimes, in rare cases, "W" may decrease to 1.0 or increase up to 3.0).

i) Using the method described above, the seasonal capacity of the peat slurry pump is calculated using equation 4-12:

$$Q_{seas} = QxTxNxK = 650x24x110x0.9$$
$$= 1,544,000\ m^3$$

j) The four values of seasonal pit length are calculated from formula 4-13:

$$L_{p1} = \frac{Q_{seas}}{(1+W_1)xBx(h-0.3)x\beta} = \frac{1,544,400}{(1+2.5)x170x(2.5-0.3)x0.9} = 1311\ m$$

where: B = 170 m, the width of the seasonal peat;
h = 2.5 m, the average depth of the seasonal peat (assumed); and
β = 0.9 assumed utilization factor for the peat deposit.

L_{p2} = 1275 m
L_{p3} = 1240 m
L_{p4} = 1207 m

Calculation of L_{des}

By placing the values of L_{p1}, L_{p2}, L_{p3}, L_{p4} from above into formula 4-9, four values of "L_{des}" for the design pipeline length are determined.

It is assumed that L_j = 225 m; L_{crit} = 850 m; then

$$L_{des1} = \frac{L_{p1} + L_j + L_{crit}}{2} = \frac{1311 + 225 + 850}{2} = 1193 \text{ m}$$

L_{des2} = 1175 m
L_{des3} = 1158 m
L_{des4} = 1141 m

The final results for the design length are shown in Table 4-2.

Determination of Optimal Pumping Distance

On the basis of data contained in Table 4-2, two curves shown in Figure 4-7 are plotted. The first curve reflects the relationship between the assumed lengths of the pipeline (l_1 = 850 m; l_2 = 950 m; l_3 = 1050 m; l_4 = 1150 m) and the peat slurry solids content (C_{sl1} = 3.1%; C_{sl2} = 3.05%; C_{sl3} = 3.0%; C_{sl4} = 2.9%). The second curve shows

TABLE 4-2

Calculated Design Length of Pipeline for Different Values of Solids Content

Assumes Values of Pipeline Length (m)	Calculated Solids Content of Peat Slurry (%)	Design Length of Pipeline (m)
850	3.10	1193
950	3.05	1175
1050	3.00	1158
1150	2.90	1141

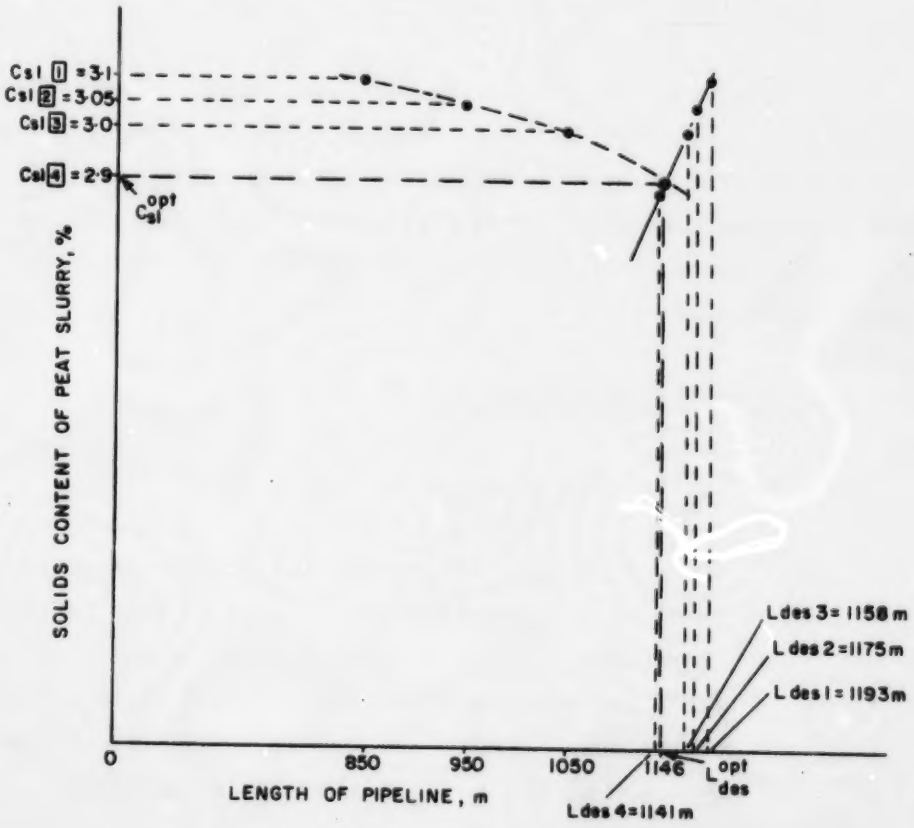


FIGURE 4-7 RELATIONSHIP BETWEEN PEAT SLURRY SOLIDS CONTENT AND PIPELINE LENGTH

the relationship between the design length of the pipeline (L_{des1} = 1193 m; L_{des2} = 1175 m; L_{des3} = 1158 m; L_{des4} = 1141 m) and the peat slurry solids content. The crossover point of the two curves determines the optimal design length of the pipeline, L_{des}^{opt} = 2.9%.

For the optimization of the mining operations for the above values, L_{des}^{opt} = 1146 m and C_{s1}^{opt} = 2.9, the corresponding values L_p^{opt} and W^{opt} must be determined using formulas 4-13 and 4-17.

$$L_p^{opt} = \frac{Q_{seas}}{(1 + W^{opt})xBx(h-0.3)x\beta} = \frac{1,544,400}{(1 + 2.8)x170x(2.5-0.3)x0.9} = 1207 \text{ m}$$

$$W^{opt} = \frac{C_{raw} - C_{s1}^{opt}}{C_{s1}^{opt}} = \frac{11.0-2.9}{2.9} = 2.8$$

Thus, for the example, the optimal length of the seasonal pit is equal to 1207 meters. The determined optimal concentration must be compared to that assumed initially for the pump curve selected. If, the determined concentration differs significantly from that assumed initially, then another pump curve will have to be selected and the analysis repeated.

.2 Graphic-Analytical Method "B"

The initial data required for the calculations are:

a) the assumed peat slurry pump performance characteristics (Q-H) as shown in Figure 4-2 (based on pump performance characteristics for water). Within the pump capacity range (between "Qmax" and "Qmin") four different values of the pump capacity are assumed, e.g., Q_1 = 450 m^3/hr; Q_2 = 600 m^3/hr; Q_3 = 750 m^3/hr; Q_4 = 900 m^3/hr;

b) the peat slurry viscosity characteristics (Figure 4-8);

c) the assumed pipeline internal diameter, e.g., D = 0.438 m; and

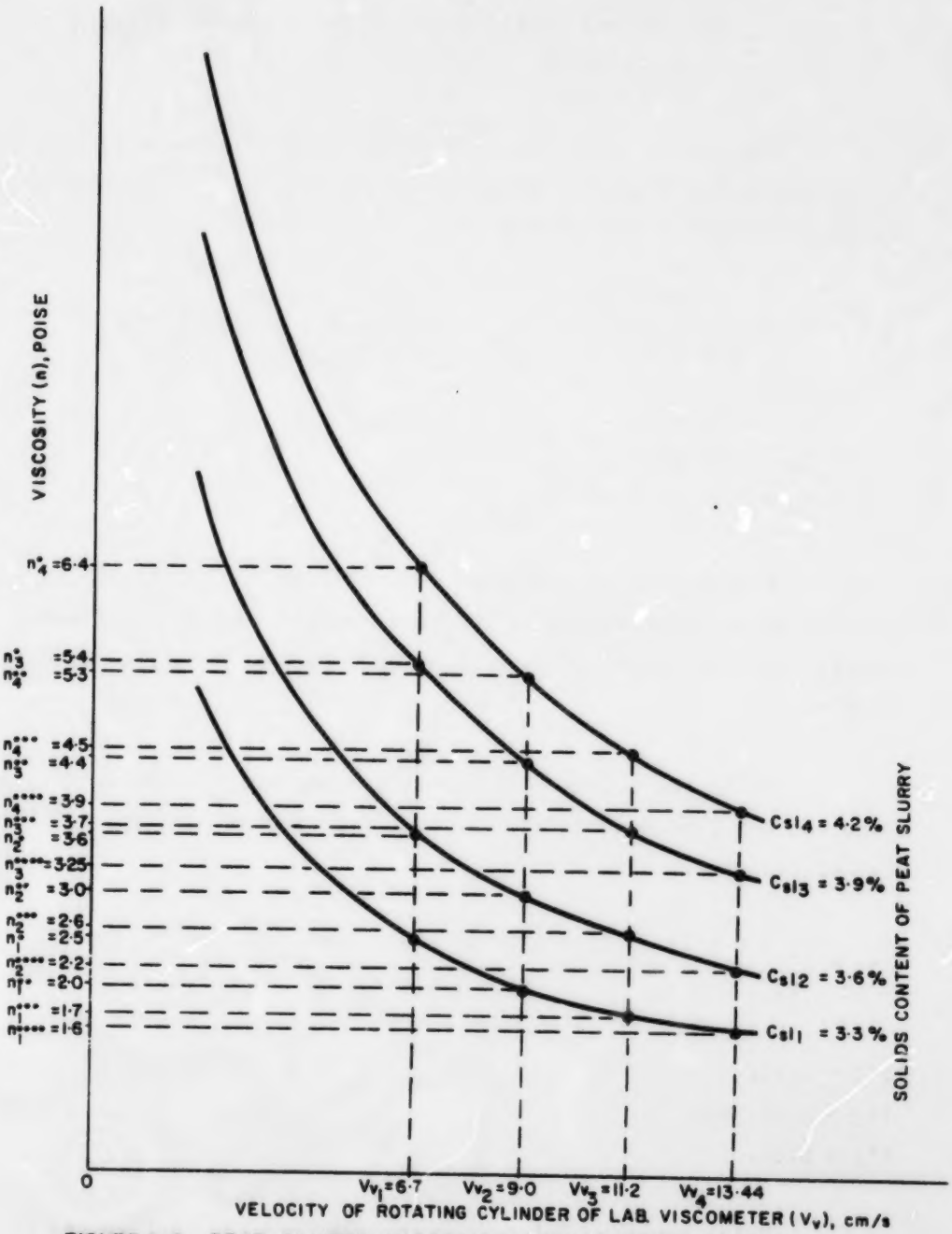


FIGURE 4-8 PEAT SLURRY VISCOSITY CHARACTERISTICS FROM LABORATORY TESTS

d) the assumed total length of the pipeline, e.g., L_{tot} = 1100 m.

The average peat slurry pipeline flow velocities V_1, V_2, V_3, V_4 corresponding to pump capacities Q_1; Q_2; Q_3; Q_4 are calculated using equation 4-2 from Method "A":

$$V_1 = \frac{4 \times Q_1}{3600 \times \P \times D^2} = \frac{4 \times 450}{3600 \times 3.14 \times 0.438^2} = 0.83 \text{ m/s};$$

V_2 = 1.11 m/s;
V_3 = 1.38 m/s; and
V_4 = 1.66 m/s.

From Figure 4-2 for the assumed values of Q_1, Q_2, Q_3, Q_4 of pump capacity, four values of the pump dynamic head (in m of water column) are determined; H_1 = 21.6 m; H_2 = 19.5 m; H_3 = 17.0 m; H_4 = 13.8 m.

Using the values of H and V, and applying the Darcy-Weisbach equation 4-4 from Method "A", the four friction factors are calculated:

$$f^*_1 = \frac{H_1 \times D \times 2g}{L_{tot} \times V_1^2} = \frac{21.6 \times 0.438 \times 2 \times 9.81}{1100 \times 0.83^2} = 0.25;$$

f^*_2 = 0.12;
f^*_3 = 0.07; and
f^*_4 = 0.04.

Using equation 4-6 from Method "A" and the four values of corresponding to V_1, V_2, V_3, V_4, four new values of the velocities of the rotating cylinder of the viscometer are determined:

$Vv_1 = 8.1xV_1 = 8.1x0.83 = 6.72$ cm/s

$Vv_2 = 8.99$ cm/s

$Vv_3 = 11.20$ cm/s

$Vv_4 = 13.44$ cm/s

Placing the values obtained for Vv into empirical formula (4-5) from Method "A", and solving it for (n), four new values of the viscosity are calculated:

$$n^*[1] = \frac{f^*_1 \times Vv_1 \times D^2}{0.16} = \frac{0.25 \times 6.72 \times 0.438^2}{0.16} = 2.0$$

$n^*[2] = 1.3$;

$n^*[3] = 0.94$; and

$n^*[4] = 0.64$.

The results of the aforementioned calculations are shown in Table 4-3.

Using the data from Table 4-3, four curves as shown in Figure 4-9 are plotted. The curves reflect the correlation of the conventional viscosity $n^*[1] = 2.0$; $n^*[2] = 1.3$; $n^*[3] = 0.94$; $n^*[4] = 0.64$, with the peat slurry solids content ($Csl_1 = 3.3\%$; $Csl_2 = 3.6\%$; $Csl_3 = 3.9\%$; $Csl_4 = 4.2\%$ at the different constant velocities of the viscometer rotating cylinder ($Vv_1 = 6.72$ cm/s; $Vv_2 = 8.99$ cm/s; $Vv_3 = 11.20$ cm/s; $Vv_4 = 13.44$ cm/s).

Four new values $C^*sl_1 = 3.1\%$; $C^*sl_2 = 3.0\%$; $C^*sl_3 = 2.8$; $C^*sl_4 = 2.6\%$ of peat slurry solids content are found for each value, $n^*[1]$, $n^*[2]$, $n^*[3]$, $n^*[4]$, from the curves shown in Figure 4-10.

Placing the values obtained for the peat slurry solids content, C^*sl_1, C^*sl_2, C^*sl_3; C^*sl_4, and four corresponding values of

TABLE 4-3

Calculated Values of Viscosities Versus Solids Content and Viscometer Velocity

Point Number	Calculated Values of Viscometer Rotating Cylinder Velocity cm/s (From page 4-23)	Solids Content of Peat Slurry (from Figure 4-8)	Viscosities of Peat Slurry (Determined from Figure 4-8), Poise	Calculated Values of Viscosities of Peat Slurry Poise (From page 4-23)
1 2 3 4	$Vv_1 = 6.72$	$Csl_1 = 3.3$ $Csl_2 = 3.6$ $Csl_3 = 3.9$ $Csl_4 = 4.2$	$n^*_1 = 2.5$ $n^*_2 = 3.6$ $n^*_3 = 5.4$ $n^*_4 = 6.4$	$n^*[1] = 2.0$
1 2 3 4	$Vv_2 = 8.99$	$Csl_1 = 3.3$ $Csl_2 = 3.6$ $Csl_3 = 3.9$ $Csl_4 = 4.2$	$n^{**}_1 = 2.0$ $n^{**}_2 = 3.0$ $n^{**}_3 = 4.4$ $n^{**}_4 = 5.3$	$n^*[2] = 1.3$
1 2 3 4	$Vv_3 = 11.20$	$Csl_1 = 3.3$ $Csl_2 = 3.6$ $Csl_3 = 3.9$ $Csl_4 = 4.2$	$n^{***}_1 = 1.7$ $n^{***}_2 = 2.6$ $n^{***}_3 = 3.7$ $n^{***}_4 = 4.5$	$n^*[3] = 0.94$
1 2 3 4	$Vv_4 = 13.44$	$Csl_1 = 3.3$ $Csl_2 = 3.6$ $Csl_3 = 3.9$ $Csl_4 = 4.2$	$n^{****}_1 = 1.6$ $n^{****}_2 = 2.2$ $n^{****}_3 = 3.25$ $n^{****}_4 = 3.9$	$n^*[4] = 0.64$

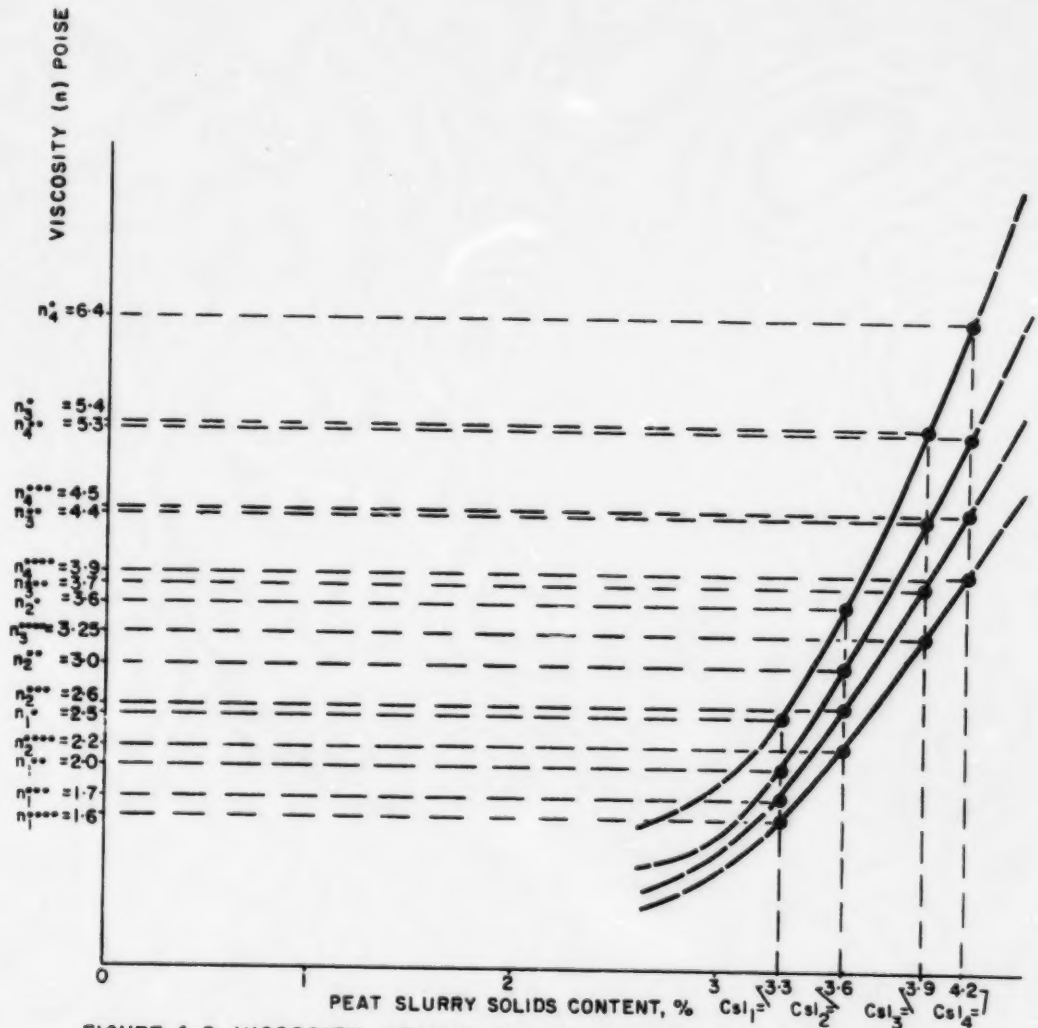


FIGURE 4-9 VISCOSITY VERSUS SOLIDS CONTENT FOR DIFFERENT VISCOMETER VELOCITIES

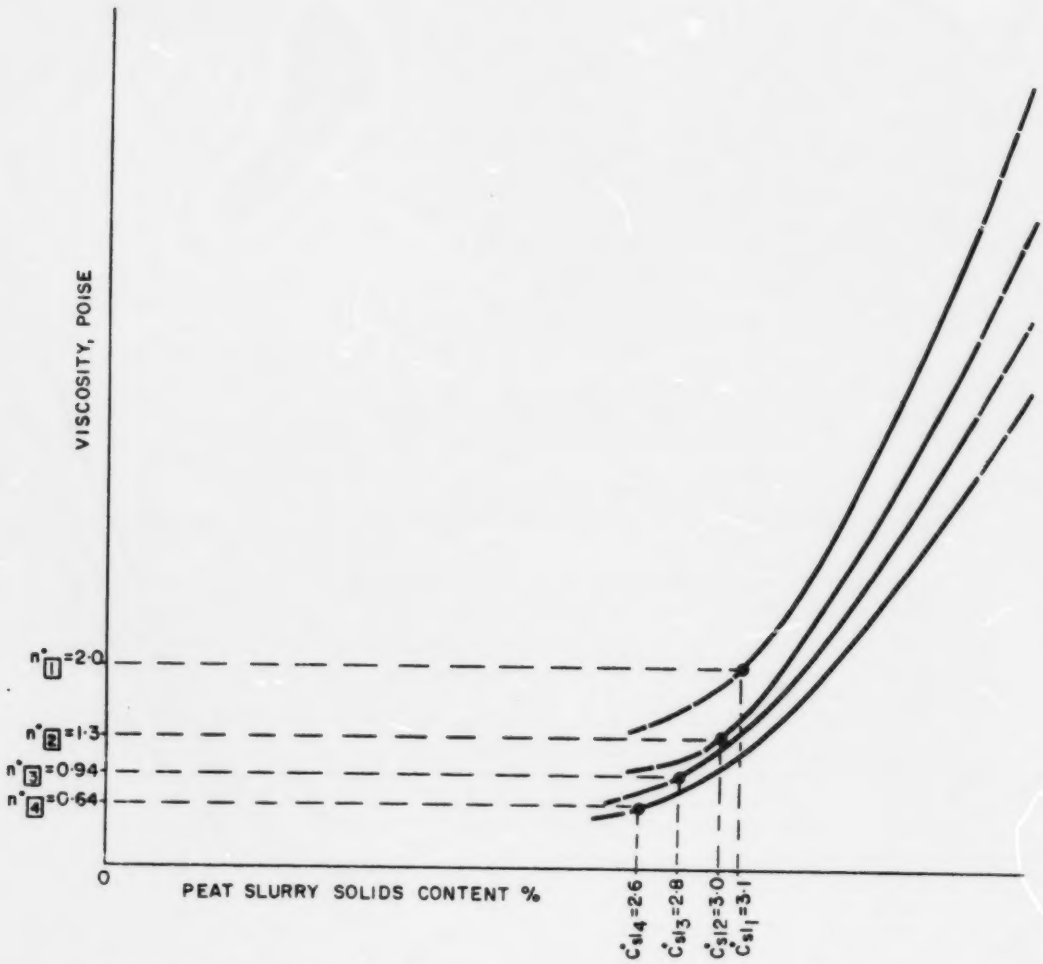


FIGURE 4-10 CALCULATED VALUES OF VISCOSITY VERSUS SOLIDS CONTENT FOR DIFFERENT VISCOMETER VELOCITIES

Q_1, Q_2, Q_3, Q_4 into equation (4-1), four values, P_1, P_2, P_3, P_4 of the peat slurry pump yield per hour (in tonnes at peat 50% moisture content) are calculated:

$$P_1 = \frac{Q_1 \times Y \times C^*sl_1}{100-Wdp} = \frac{450 \times 1 \times 3.1}{100-50} = 27.8 \text{ tonnes/hr}$$

P_2 = 35.8 tonnes/hr;
P_3 = 42.3 tonnes/hr; and
P_4 = 46.8 tonnes/hr.

The final results of the 2nd method of calculation are shown in Table 4-4. In Table 4-4, the maximal pump yield is equal P_4 = 46.8 tonnes/hr when the pump capacity, Q = 900 m^3/hr. It should be noted that solids content C^*sl_4 = 2.6% corresponding to the maximal pump capacity (Q_4 = 900 m^3/hr) will be optimal only if the assumed pipeline length, Ltot = 1100 m, is equal to the design pipeline length (Ldes) as found with the first calculation method. This will occur if the first calculation method is made using the four assumed pump capacities (Q_1, Q_2, Q_3, Q_4). In each case, a new Ldes will be calculated. "Ldes" can be plotted against "Q", and where the curve intersects Ltot = 1100 m, the optimum conditions are assumed to be met.

The data and results obtained are shown in Table 4-5. From Table 4-5, it can be found that the design length the "Ldes" is closest to the assumed length "Ltot" at 600 m^3/hr (one can interpolate for closer accuracy as shown in Figure 4-11). At this point, the yield of peat (50% m.c.) is 35.8 tonnes/hr and Csl opt. = 2.98%.

TABLE 4-4
Final Results of Maximum Peat Slurry Pump Capacity and Optimal Solids Content

Item	Unit	Variable			
Theoretical Capacity of Peat Slurry Suction Pump	m^3/hr	450	600	750	900
Dynamic Head	m water column	21.6	19.5	17.0	13.8
Peat Slurry Pipeline Velocities	m/s	0.83	1.11	1.38	1.66
Calculated Values of the Velocities of the Viscometer	cm/s	6.72	8.99	11.20	13.44
Assumed Pipeline Length	m	1100	1100	1100	1100
Calculated Values of Viscosity	Poise	2.0	1.3	0.94	0.64
Values of Peat Slurry Solids Content as Determined From Graphs	%	3.1	3.0	2.8	2.6
Peat Yield (50% Moisture)	tonnes/hr	27.8	35.8	42.3	46.8
Maximum Peat Slurry Pump Capacity Corresponding to Maximal Peat Yield (tonnes of peat, 50% moisture)	m^3/hr				900
Peat Slurry Solids Content Corresponding to the Maximum Peat Slurry Pump Capacity	%				2.6

TABLE 4-5
Comparison of Peat Slurry Pump Capacity, Peat Yield, Design Length of Pipeline and Optimum Solids Concentration

Variable	Capacity of Peat Slurry Pump (m^3/hr)	Peat Yield (50% m.c. tonnes/hr)	Calculated Design Length of Pipeline (m)	Optimum Peat Slurry Solids Content (%)
1	900	46.8	1265	2.52
2	750	42.3	1202	2.76
3	600	35.8	1111	2.98
4	450	27.8	995	3.17

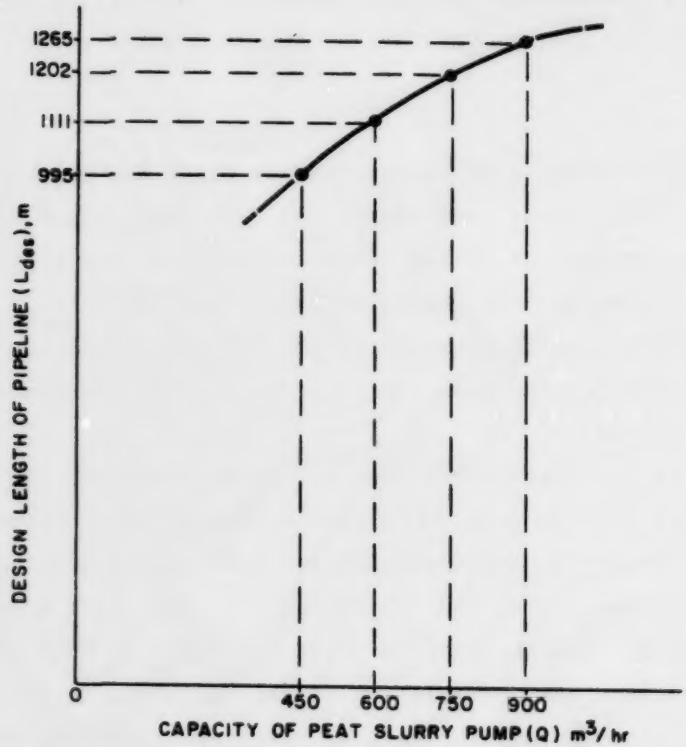


FIGURE 4-11 PIPELINE LENGTH VERSUS PUMP CAPACITY

4.5 BOTANICAL SPECTRUM METHOD OF CALCULATING THE OPTIMAL PEAT SLURRY SOLIDS CONTENT

In addition to the previously described graphic-analytical methods, the optimal peat slurry solids content can also be determined by using information on the characteristics of the type of peat. Unlike the graphic-analytical methods which can be also used to determine various pumping parameters, the botanical spectrum method is useable only for the peat slurry solids content determination.

A correlation has been established between the optimum (as defined earlier on Page 123) peat slurry solids content and the type of peat, degree of decomposition and ash content based on previous USSR experience using the "hydropeat" wet peat mining method. Table 4-6 is taken from the Russian "Peat Engineers Handbook (Moscow, 1954)" and represents the accumulation of decades of statistical data on peat slurry concentrations for various peat types achieved using the "hydropeat" mining method. The information was commonly used for engineering design calculations of output. Inasmuch as it appears that a positive correlation can be made between North American and Russian peats, the information can be useful where wet mining systems for North American peats are considered, using similar technology for extraction. This information is summarized in Table 4-6. Besides the information contained in Table 4-6, data describing the particular peat deposit is required.

Table 4-7 is an example of data obtained from an actual peat deposit and shows a relatively small variation in peat type and degree of decomposition. The percentage degree of decomposition was determined by the laboratory centrifugal method. The information in Tables 4-6 and Table 4-7 can be grouped together as in Table 4-8 for a preliminary determination of solids content. The values of the peat slurry solids content in Table 4-8, column 5, are taken from Table 4-6

TABLE 4-6

Optimal Solids Contents for Industrial Peat Slurries Versus Peat Type, Degree of Decomposition, and Ash Content

Peatland Type	Peatland Sub-Type	Peat Group	Individual Peat Type	Ash Content %	Degree of Decomposition, %														
					0-3	5	10	15	20	25	30	35	40	45	50	55	60	65	70
					Solids Content of Industrial Peat Slurry, %														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Lowmoor	Swamp	Wood Peats	Alnus, Betula, Picea (Pinus, Solix)	13.0	-	-	-	-	2.95	3.92	4.92	5.87	6.67	7.35	7.87	8.20	8.45	8.70	-
	Treed-Fen	Wood-Herb Peats	Wood-Phragmites	12.0	-	-	-	-	-	3.42	4.42	5.45	6.33	7.06	7.55	8.00	8.35	8.60	-
			Wood-Sedge	11.0	-	-	-	-	3.17	4.43	5.15	6.01	6.82	7.55	8.02	8.45	8.70	8.90	-
		Wood-Moss Peats	Wood-Hypnum	10.0	-	-	-	-	3.45	4.10	4.82	5.50	6.15	6.68	7.13	7.47	7.72	-	-
			Wood-Sphagnum	9.0	-	-	-	-	3.33	3.98	4.75	5.47	6.12	6.71	7.22	7.59	7.86	-	-
	Fen	Herb Peats	Sedge	6.5	-	2.38	2.95	3.47	3.86	4.12	4.34	4.62	4.98	5.37	5.75	6.20	-	-	-
			Scheuchzeria	5.5	-	-	2.52	2.97	3.47	3.87	4.35	4.85	5.33	5.81	6.24	6.63	-	-	-
			(Equisetum	10.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Phragmites	9.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Menyanthes)	7.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Average of Herb Peats Group:				2.38	2.73	3.22	3.67	4.00	4.35	4.74	5.16	5.59	6.00	6.42	-	-	-
		Herb-Moss Peats	Sedge-Hypnum	6.7	-	2.42	2.97	3.45	3.87	4.21	4.53	4.90	5.28	5.59	6.09	6.42	-	-	-
			Sedge-Sphagnum	6.3	-	2.15	2.70	3.20	3.70	4.10	4.45	4.85	5.25	5.72	6.16	6.59	-	-	-
		Moss Peats	Hypnum	7.0	-	2.47	2.99	3.45	3.87	4.27	4.72	5.13	5.63	6.01	6.39	-	-	-	-
			Sphagnum	6.0	1.68	1.93	2.44	2.96	3.52	4.05	4.58	5.07	5.56	6.07	6.54	-	-	-	-

TABLE 4-6 (Cont'd)

Optimal Solids Contents for Industrial Peat Slurries Versus Peat Type, Degree of Decomposition, and Ash Content

Peatland Type	Peatland Sub-Type	Peat Group	Individual Peat Type	Ash Content %	Degree of Decomposition, %														
					0-3	5	10	15	20	25	30	35	40	45	50	55	60	65	70
					Solids Content of Industrial Peat Slurry, %															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Transitional Moor	Swamp Treed-Fen Bog	Wood Peats	Wood	6.0	-	-	-	-	-	3.15	3.85	4.60	5.28	5.93	6.47	6.92	7.27	-	-
		Wood-Herb Peats	Wood-Sedge	5.0	-	-	-	2.58	3.15	3.65	4.27	4.91	5.59	6.15	6.63	7.01	7.26	-	-
		Wood-Moss Peats	Wood-Sphagnum	5.0	-	1.90	2.25	2.70	3.10	3.61	4.14	4.76	5.34	5.91	6.30	6.75	7.04	-	-
	Open Fen Bog	Herb Peats	Sedge	4.5	-	-	-	2.58	3.28	3.96	4.68	5.22	5.89	6.36	6.78	7.10	7.25	-	-
			Scheuchzeria	4.0	-	-	-	2.58	3.28	3.96	4.68	5.22	5.89	6.36	6.78	7.10	7.25	-	-
		Herb-Moss Peats	Sedge-Sphagnum	4.0	-	1.90	2.25	2.70	3.25	3.92	4.55	5.07	5.65	6.12	6.51	6.84	-	-	-
		Moss Peats	Sphagnum (Hypnum)	4.0-4.5	1.64	1.90	2.18	2.75	3.10	3.87	4.42	4.92	5.40	5.88	6.24	6.51	-	-	-
Highmoor	Pine Bog	Wood Peats	Pinus	4.0	-	-	-	-	-	-	-	4.90	5.50	5.90	6.40	6.80	7.30	7.65	8.00
	Forested Bog	Wood Herb Peats	Pinus-Eriophorum	4.0	-	-	-	-	-	3.87	4.25	4.70	5.06	5.44	5.84	6.30	6.70	7.20	7.65
		Wood-Moss Peats	Pinus-Sphagnum	4.0	-	-	-	-	-	3.87	4.26	4.70	5.06	5.44	5.84	6.30	6.70	7.20	7.60

TABLE 4-6 (Cont'd)

Optimal Solids Contents for Industrial Peat Slurries Versus Peat Type, Degree of Decomposition, and Ash Content

Peatland Type	Peatland Sub-Type	Peat Group	Individual Peat Type	Ash Content %	Degree of Decomposition, %														
					0-3	5	10	15	20	25	30	35	40	45	50	55	60	65	70
					Solids Content of Industrial Peat Slurry, %															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Highmoor	Open Moor	Herb Peats	Eriophorum Scheuchzeria	3.5	-	-	-	-	3.40	3.83	4.25	4.65	5.04	5.49	5.80	6.40	6.80	-	-
	Open Bog	Herb-Moss Peats	Eriophorum-Sphagnum	2.8	-	1.72	1.98	2.28	2.55	2.86	3.22	3.50	4.02	4.51	5.00	-	-	-	-
			Scheuchzeria-Sphagnum	2.5	-	1.73	2.21	2.60	2.97	3.34	3.75	4.19	4.65	5.20	5.67	-	-	-	-
		Moss Peats	Medium	2.9	1.73	1.87	2.15	2.41	2.65	2.97	3.35	3.76	4.15	4.67	-	-	-	-	-
			Fuscum	2.7	1.86	2.02	2.35	2.55	2.99	3.35	3.77	4.23	4.75	5.29	-	-	-	-	-
			Mixed-Moss	2.4	1.60	1.73	2.15	2.58	2.99	3.37	3.81	4.28	4.77	5.29	-	-	-	-	-
			Sphagnum-Cuspidatum	2.2	1.78	2.01	2.64	3.29	3.87	-	-	-	-	-	-	-	-	-	-
-	-	-	Sapropel	9.0	6.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-

SOURCE: Samsonov, N.N. (Editor). Peat Engineers Handbook, Moscow, 1954.

TABLE 4-7

An Example of the Botanical Spectrum Evaluation of a Parry Sound, Ontario Peat Deposit

Thicknesses of Sampled Layers, m	Peat Type	Average Degree of Decomposition of each Layer, %
0.4	Transitional Sedge-Sphagnum	20
0.3	Transitional Sedge-Sphagnum	20+
0.3	Transitional Sedge-Sphagnum	20+
0.2	Transitional Sedge-Sphagnum	20
0.2	Transitional Sphagnum-Sedge	20
0.2	Transitional Sphagnum-Sedge	25
0.2	Transitional Sedge-Sphagnum	25

TABLE 4-8

An Example of the Determination of Optimal Slurry Solids Concentration Using Botanical Spectrum Method of Calculation - Parry Sound, Ontario Peat

Borehole No.	Peat Type	Average Degree of Decomposition, %	Thicknesses of Sampled Layers, m	Peat Slurry Solids Content for each Layer (from Table 4-6)	Product of Columns 4x5	Ash Content %	Product of Columns 4x7
1	2	3	4	5	6	7	8
	Transitional Sedge-Sphagnum	20	0.4	3.25	1.30	4.0	1.6
	Transitional Sedge-Sphagnum	20	0.3	3.25	0.975	4.0	1.2
	Transitional Sedge-Sphagnum	20	0.3	3.25	0.975	4.0	1.2
	Transitional Sedge-Sphagnum	20	0.2	3.25	0.65	4.0	0.8
	Transitional Sphagnum-Sedge	20	0.2	3.10	0.62	4.0	0.8
	Transitional Sphagnum-Sedge	25	0.2	3.87	0.774	4.0	0.8
	Transitional Sedge-Sphagnum	25	0.2	3.92	0.784	4.0	0.8
Results			1.8	3.4	6.08	4.0	7.2

and they correspond to the appropriate layers of the peat deposit as shown in Table 4-7. The average optimal slurry pumping solids content for the given peat deposit is 3.4% determined as the weighted average result.

The calculation of the average ash content for a given peat deposit is determined in a similar manner by weighting the ash values by corresponding thicknesses giving an average weighted ash content of 4.0%.

The 0.3 m thickness of the bottom layer of the peat deposit (for reclamation purposes) is excluded from the total depth of the sampled peat deposit, and also any peat layers containing more than 20% ash content.

If the moisture content varies significantly from layer to layer (2% or more) a more detailed determination, considering each layer separately, must be carried out. An example of the approach is given in Table 4-9. Column 4 includes the moisture content information, column 5 is determined from known characteristics of peat. The products of the above values are multiplied by the thickness of the layer and the result used to weight the individual slurry solids content values determined from Table 4-6 for each layer. A weighted average slurry solids content for the portion of the deposit of interest is thereby determined taking into consideration the variation in moisture content of each layer.

The calculation of the peat slurry solids content described above applied to the average industrial application. Where non-standard mining of peat size, higher or lower stump content, frozen lumps of peat, ash content variation, etc. conditions are encountered, correction factors should be introduced.

TABLE 4-9

An Example of the Determination of Optimal Slurry Concentration Using Botanical Spectrum Method with Peat Layers of Varying Moisture Content

Sub-Sample Peat Type	Thickness of Sampled Layers (m)	Average Degree of Decomposition (%)	Solids Content of the In-Situ Peat Layers %	Volume Weight* of the In-Situ Peat Layers %	Product of Columns 2x4x5	Peat Slurry Solids Content for each Sub-Sample Layer (from Table 4-6) (%)	Product of Columns 6x7
1	2	3	4	5	6	7	8
Highmoor-medium	0.25	15	7.0	1.06	1.855	2.4	4.45
Highmoor-medium	0.15	20	7.0	1.06	1.113	2.6	2.89
Highmoor-medium	0.10	20	7.0	1.06	0.742	2.6	1.93
Eriophorum-sphagnum	0.25	25	9.0	1.04	2.34	2.9	6.79
Scheuchzeria-sphagnum	0.25	25	9.0	1.04	2.34	3.3	7.72
Transitional-sedge	0.30	30	11.0	1.02	9.18	4.7	43.15
Highmoor-mixed	0.30	35	11.0	1.02	10.71	4.3	46.05
Wood-phragmites	0.40	35	13.0	1.00	14.00	5.4	75.60
Wood-sedge	0.40	40	13.0	0.98	15.68	6.8	106.62
Results	2.4				57.96	5.1	295.20

*Peat Engineers Handbook, Moscow, 1954.

The above results may be checked against similar data obtained for the same samples from the laboratory viscosity tests described earlier in Part 4. The botanical spectrum method (using Table 4-6) is based on statistical data obtained over a period of industrial practice in the USSR. Use of the method in a practical wet peat mining development application to determine optimal peat slurry solids concentration is dependent on the accumulation of further analagous information on North American peat types.

4.6 ASSESSMENT OF THE METHODS

The optimal peat slurry solids content is one of the most important parameters necessary for mining design and calculations. For example, it is needed for calculation of the dry peat yield from 1 cubic meter of peat slurry, for calculations of the amount of water required for the hydromonitors, for calculation of the length of the seasonal mining pit, etc.

As mentioned earlier, this parameter may be determined by graphic-analytical as well as botanical spectre methods. The principal difference between the methods is based on the intrinsic features of the data used in each case. For the graphic-analytical methods "A" and "B", the viscosity characteristics of the prospective peat slurry are required. For the botanical spectrum method, information on the peat characteristics is considered: type of peat, moisture content, degree of decomposition, ash content, etc.

The advantage of the graphic-analytical method, compared to the botanical spectrum method, is that the former allows calculation, not only of the optimal peat slurry solids content, but also of other important parameters, such as optimum pump capacity, maximum length of the pipeline, friction losses, etc.

The choice of using one of the above methods depends on the possibility of obtaining the required initial data for the particular case. As shown by industrial experience in the USSR, at the initial stages of development of wet peat mining technology, the graphic-analytical methods prevailed for the calculation of optimal solids content. Later, when more data was accumulated, the other method, based on use of tables (e.g. 4-6) became more convenient and widely used.

Although correlation of peat and peatland type information between the USSR and North America appears positive, more data is required before the botanical spectrum method can be used with assurance, and therefore its use should be for preliminary indications of slurry solids content using wet peat mining technology (hydro-peat). The graphic-analytical methods are recommended for actual wet mining system design.

APPENDIX A

METHOD OF DETERMINATION OF DEGREE OF DECOMPOSITION OF PEAT (USSR GOST STANDARD)

UDC 622.331:543.06(083.74)

Group A19

STATE STANDARD OF THE USSR

PEAT
Method of Determination of Decomposition Degree

GOST
10650-72
Supersedes GOST
10650-65

By the decision of the State Committee of Standards of the Council of Ministers of the USSR as of August 16, 1972, No. 1609, the effective term is established since January 1, 1974 up to January 1, 1979.

Non-observance of State Standard is Prosecuted by Law

The present standard specified the method of determination of the decomposition degree of the peat sampled from peat accumulations.

The degree of peat decomposition means percentage of the structure less mass containing fine particles of the non-humificated substances along with human substances.

The Standard is not applicable for the processed peat.

The method consists in separation of the coagulated humus from fiber by sieve analysis in water with formation of the deposits by centrifuging and with subsequent determination of the decomposition degree on the chart.

1. Equipment, Materials and Reagents

Electric centrifuge, type IIAK-1, manufactured by Frunze Plant.
Test-tube holder for the centrifuge (Fig. A-1).

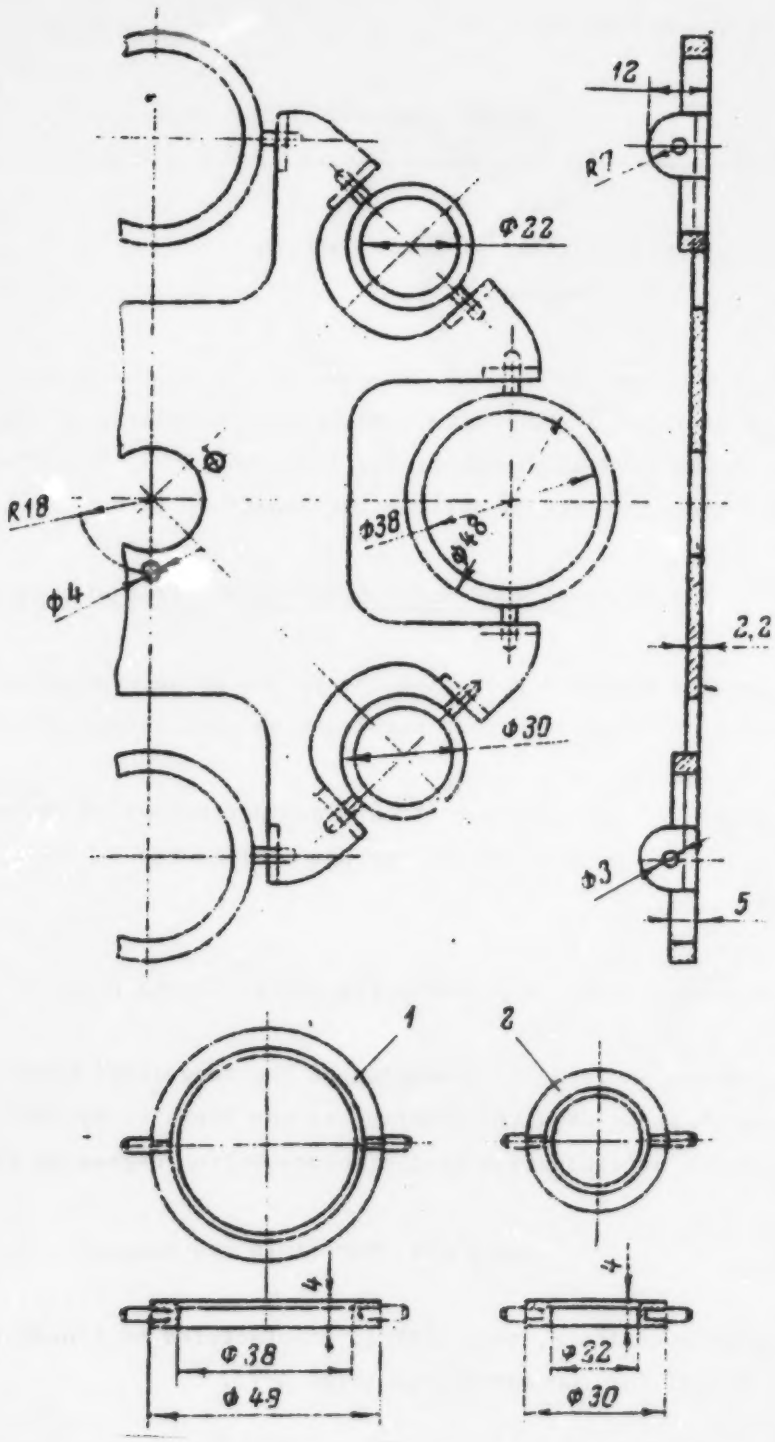


FIGURE A-1 CENTRIFUGE TEST TUBE HOLDER

Time relay, type 16 - 1 PBM.

Large and small test tubes (Fig. A-2).

Beaker with sieve (Fig. A-2), mesh No. 025K, GOST 3584-5.

Sampler with piston (Fig. A-3).

Porcelain cups Nos. 7 and 8, GOST 9147-59.

Ferric chloride, 10% aqueous solution, 2263-71.

Hydrochloric acid, 1 x solution, GOST 1382-69.

Caustic soda, commercial, 1 x solution, GOST 2363-71.

Postassium hydroxide (caustic potash), commercial, 1 x solution, GOST 9285-69.

Stand, dropper, cyrstallizer, rubber bulk, tea spoon.

2. Preparation for Testing

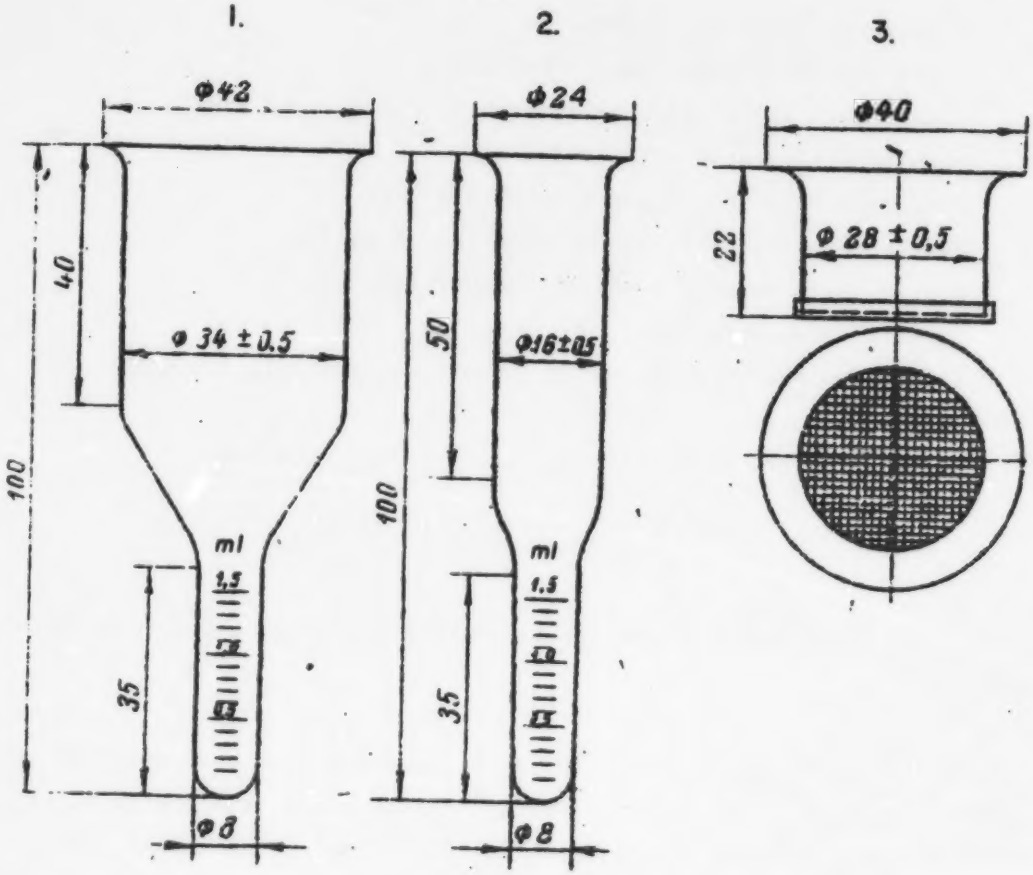
2.1. Preparation of peat sample with humidity of equal to or more than 65%.

Take a peat sample, 100 - 200 g in mass, from the test specimen, GOST 17644-72, spread it in an even layer, 3 - 4 mm thick, and pierce it with a sampler throughout the entire depth in 10 - 12 points uniformly arrange on the entire area.

2.2. Preparation of peat sample with humidity less than 65%.

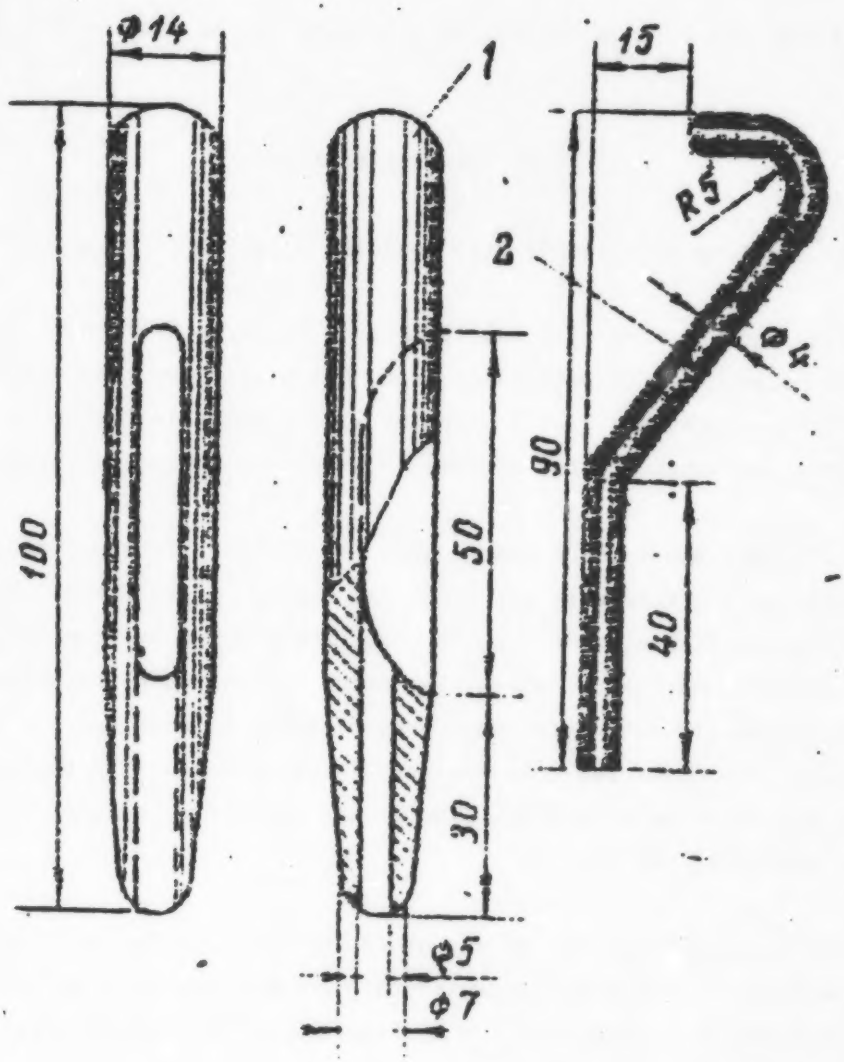
The peat sample with the humidity less than 65% should be preliminarily processed. Arrange some of the peat sample in a porcelain cup so that after swelling the peat will fill the cup by 2/3 - 3/4 of its volume) and pour the alkali solution (caustic soda or caustic potash).

After 24 - 30 hours, carefully agitate the peat sample, break the lumps and, if the sample is still lumpy, add some alkali until the mass becomes homogeneous.



1. LARGE TEST TUBE
2. SMALL TEST TUBE
3. BEAKER WITH SEIVE

FIGURE A-2 TEST TUBES AND BEAKER



1. SAMPLER
2. PISTON

FIGURE A-3 PISTON SAMPLER

Take the sample from the cup by a sampler or tea spoon and process to testing.

3. Testing Procedure

3.1. Testing peat sample with humidity equal to or more than 65%.

3.1.1. Arrange the peat sample taken in accordance with Item 2.1 in a small test tube, fill it with water (1 cm below the test tube edge), mix the sample with a stick, add 2 or 3 drops of ferric chloride for humus coagulation, and shake up the mixture to produce homogeneous suspension.

3.1.2. After obtaining homogeneous suspension, fit the test tube into the centrifuge and rotate it for 2 min. at a speed of 1000 rpm. Having stopped the centrifuge, take out the test tube and measure the volume of the deposit against the test tube scale accurate to hundredth fractions. If the sediment surface is not horizontal, take readings by reference to a middle line between the upper and lower points of the surface. The boundary of the sediment should be well defined. The liquid above the sediment should be free from the suspended matter.

After centrifuging, the amount of the sediment in the small test tube should be 0.7 - 1.5 ml which approximately corresponds to a batch of 0.3 - 0.5 g. For the peat characterized by high degree of decomposition, the amount of the sediment should be 0.7 - 1.0 ml.

3.1.3. Mix the substances contained in the small test tube and transfer them into the beaker with the sieve held over a large test tube. Wash off the peat particles stuck to the small test tube walls with 3 - 4 ml of water.

3.1.4. Arrange the large test tube together with the beaker in the centrifuge and rotate it for 2 min. at a speed of 1000 rpm.

After the centrifuge comes to a standstill, take out the test tube and measure the amount of the subsieve fraction sediment accurate to 0.01 ml.

3.2. Testing peat sample with humidity less than 65%.

3.2.1. Arrange the peat sample taken in accordance with Item 2.2 in a small test tube, fill the hydrochloric acid solution to half the test tube height, mix the sample with a stick, carefully shake it up and leave it for 3 - 5 min. until the neutralization reaction is over.

3.2.2. Add water into the test tube (1 cm below the edge), fill five drops of ferric chloride and shake up the sample once more.

Then proceed as instructed in items 3.1.2 - 3.1.4.

Note. When testing, the sieves should be kept in a cup with water to preclude their excessive corrosion from the acid. Before proceeding as instructed in Item 3.1.3, the acid solution contained over the sediment in a small test tube should be carefully drained, without stirring up the sediment, then, fill the test tube with water and add 1 or 2 drops of ferric chloride.

4. Processing Test Results

4.1. Determine the degree of decomposition by reference to a chart shown on Fig. A-4. To this end, plot the value of the amount of the sediment in the small test tube on the X-axis and the value of the amount of the sediment in the large test tube on the Y-axis.

Proceed along the straight line located close to the point of intersection of the two lines and find the value of the peat decomposition degree on the right scale.

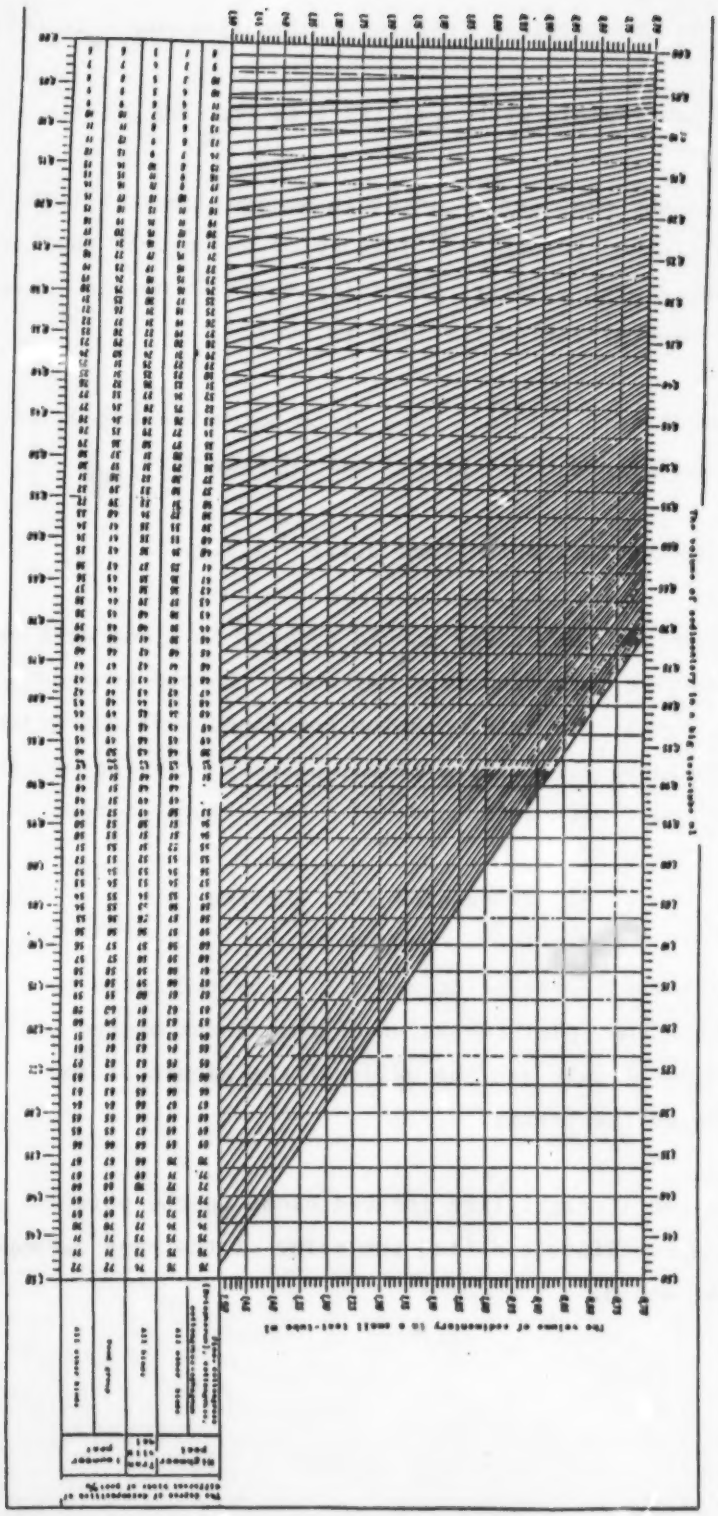


FIGURE A-4
CHART FOR THE DETERMINATION
OF THE DEGREE OF DECOMPOSITION
OF PEAT

4.2. For calculation of the test results, fill in the Log indicated in Appendix 2.

If the ash content of the peat equals 15% or more, introduce the appropriate corrections into the obtained values of the decomposition degrees in accordance with Table 1.

Table A-1

Peat ash content, %	Correction for decomposition degree, %
Up to 15	-
From 15 to 25	2
From 25 to 35	3
From 35 to 45	4
From 45 to 55	5

4.3. For determining the degree of peat decomposition, take four measurements on one peat sample.

4.4. The accuracy of determination of the decomposition degree is specified in Table 2.

Table A-2

Peat moisture content, %	Peat decomposition degree, %			
	1-15	15-30	30-50	50 and over
Over 65	±1.5	±2	±3	±5
Below 65	±2	±3	±5	±5

4.5. The difference between the maximum and minimum value of the peat decomposition degrees determined during four parallel measurements are indicated in Table 3.

Table A-3

Peat moisture content, %	Permissible difference, %, for peat decomposition degree			
	1-15	15-30	30-50	50 and over
Over 65	4	6	9	15
Below 65	6	9	15	15

Table A-4

Example of Log Keeping

Sample 156, low sedge peat

Test Tube No.	Volume of sediment, ml		Peat decomposition degree, %
	in small test tube	in large test tube	
1	0.97	0.52	41
2	0.93	0.50	41
3	0.97	0.51	40
4	0.99	0.55	42

The average value of the decomposition degree 164:4 = 41%.

With introduction of correction for ash content (A^C = 30%)

41-3 = 38%.

APPENDIX B

DEGREE OF DECOMPOSITION - ORF LABORATORY TEST RESULTS

DEGREE OF DECOMPOSITION TEST RESULTS - Parry Sound (Ontario) Peat Sample, Transitional Moor Peatland, Sedge-Sphagnum and Sphagnum-Sedge Types of Peat

(Sample No. 1, 0.6 to 1.2 m; sample No. 2, 1.2 to 1.6 m; sample No. 3, 1.6 to 1.9 m)

Sub-Sample No.	Depth Approx. (cm)	Run No.	Small Tube Volume (mL)	Large Tube Volume (mL)	% Decomposition	% Difference	Average	% Ash	Adjusted % Decomp	Von Post
C2-1	60 - 70	1	0.92	0.20	19.5					
			1.18	0.20	17.5	5.0	17.3	4.75	17.3	H6
			0.80	0.16	17.5					
			1.05	0.16	14.5					
		2	0.69	0.13	17.0					
			0.91	0.18	17.5	4.5	15.6	4.75	15.6	H6
			0.74	0.12	15.0					
			0.85	0.11	13.0					
C2-2	70 - 80	1	1.30	0.14	11.0					
			1.10	0.16	13.5	5.0	11.9	3.03	11.9	H6
			0.93	0.14	14.0					
			1.35	0.10	9.0					
		2	0.99	0.25	21.0					
			1.10	0.21	17. 5	5.0	18.9	3.03	18.9	H6
			1.35	0.20	16.0					
			1.00	0.23	21.0					
C2-3	80 - 90	1	1.05	0.14	13.0					
			0.99	0.18	17.0	4.0	14.5	5.39	14.5	H6
			1.30	0.20	15.0					
			1.15	0.15	13.0					
		2	1.05	0.21	18.0					
			1.00	0.21	19.0	2.5	17.6	5.39	17.6	H6
			1.18	0.20	16.5					
			1.08	0.20	17.0					

Contd....

DEGREE OF DECOMPOSITION TEST RESULTS - Parry Sound (Ontario) Peat Sample, Transitional Moor Peatland, Sedge-Sphagnum and Sphagnum-Sedge Types of Peat

(Sample No. 1, 0.6 to 1.2 m; sample No. 2, 1.2 to 1.6 m; sample No. 3, 1.6 to 1.9 m)

Sub-Sample No.	Depth Approx. (cm)	Run No.	Small Tube Volume (mL)	Large Tube Volume (mL)	% Decomposition	% Difference	Average	% Ash	Adjusted % Decomp	Von Post
C2-4	90 - 100	1	1.50	0.2	13.0					
			1.30	0.2	13.0	2.0	14.0	11.47	14.0	H6
			1.30	0.2	15.0					
			1.50	0.23	15.0					
		2	1.05	0.20	17.0					
			1.10	0.20	17.0	2.5	16.3	11.47	16.3	H6
			1.40	0.21	14.5					
			1.50	0.25	16.5					
C2-5	100 - 110	1	1.20	0.18	15.0					
			1.30	0.24	17.0	5.0	17.1	7.7	17.1	H6
			1.19	0.20	16.5					
			0.95	0.21	20.0					
		2	1.30	0.20	15.0					
			1.00	0.18	17.0	2.0	16.4	7.7	16.4	H6
			0.95	0.17	17.0					
			1.23	0.21	16.5					
C2-6	110 - 120	1	1.20	0.15	13.0					
			1.28	0.10	15.0	6.0	13.0	4.00	13.0	H6
			1.40	0.12	9.0					
			0.96	0.15	15.0					
		2	0.71	0.20	23.0					
			0.95	0.20	19.0	6.0	21.5	4.00	21.5	H6
			0.78	0.24	25.0					
			0.95	0.20	19.0					

Contd....

DEGREE OF DECOMPOSITION TEST RESULTS - Parry Sound (Ontario) Peat Sample, Transitional Moor Peatland, Sedge-Sphagnum and Sphagnum-Sedge Types of Peat

(Sample No. 1, 0.6 to 1.2 m; sample No. 2, 1.2 to 1.6 m; sample No. 3, 1.6 to 1.9 m)

Sub-Sample No.	Depth Approx. (cm)	Run No.	Small Tube Volume (mL)	Large Tube Volume (mL)	% Decomposition	% Difference	Average	% Ash	Adjusted % Decomp	Von Post
C2-7	120 - 130	1	1.10	0.26	21.0					
			1.20	0.28	21.0	5.0	18.8	5.76	18.8	H7
			1.10	0.19	17.0					
			1.35	0.22	16.0					
		2	1.40	0.20	14.0					
			1.11	0.20	17.0	4.0	15.3	5.76	15.3	H7
			1.05	0.20	17.0					
			1.20	0.15	13.0					
C2-8	130 - 140	1	0.98	0.12	13.0					
			1.10	0.15	13.0	2.0	13.5	6.14	13.5	H7
			0.80	0.13	15.0					
			1.15	0.15	13.0					
		2	0.80	0.20	21.0					
			0.80	0.20	21.0	4.0	19.0	10.8	19.0	H7
			1.05	0.19	17.0					
			0.89	0.17	17.0					
C2-9	140 - 150	1	0.73	0.20	22.0					
			0.86	0.20	20.5	3.5	22.4	8.25	22.4	H7
			0.90	0.25	24.0					
			1.20	0.30	23.0					
		2	0.99	0.26	23.5					
			0.94	0.19	18.5	5.0	20.9	8.25	20.9	H7
			0.89	0.20	20.0					
			0.88	0.22	21.5					

Contd....

DEGREE OF DECOMPOSITION TEST RESULTS - Parry Sound (Ontario) Peat Sample, Transitional Moor Peatland, Sedge-Sphagnum and Sphagnum-Sedge Types of Peat

(Sample No. 1, 0.6 to 1.2 m; sample No. 2, 1.2 to 1.6 m; sample No. 3, 1.6 to 1.9 m)

Sub-Sample No.	Depth Approx. (cm)	Run No.	Small Tube Volume (mL)	Large Tube Volume (mL)	% Decomposition	% Difference	Average	% Ash	Adjusted % Decomp	Von Post
C2-10	150 - 160	1	1.05	0.20	17.0					
			1.00	0.21	18.5	5.0	18.8	36.3	15.3	H7
			0.75	0.20	22.0					
			0.91	0.18	17.5					
		2	1.01	0.22	20.0					
			1.08	0.28	22.5	5.5	20.4	36.3	16.9	H7
			1.15	0.20	17.0					
			0.75	0.20	22.0					
C2-11	160 - 170	1	0.92	0.21	20.5					
			0.95	0.25	23.0	7.0	19.6	31.1	16.6	H8
			0.90	0.15	16.0					
			0.84	0.18	19.0					
		2	0.70	0.22	25.0					
			0.80	0.30	30.0	5.0	26.4	31.1	23.4	H8
			0.80	0.25	25.5					
			0.85	0.25	25.0					
C2-12	170 - 180	1	0.82	0.22	22.5					
			0.86	0.20	21.0	3.5	21.0	37.9	17.0	H8
			1.00	0.21	19.0					
			0.74	0.19	21.5					
		2	0.70	0.21	24.0					
			0.95	0.24	22.5	1.5	23.3	37.9	19.3	H8
			0.71	0.19	22.5					
			0.90	0.25	24.0					

Contd....

DEGREE OF DECOMPOSITION TEST RESULTS - Parry Sound (Ontario) Peat Sample, Transitional Moor Peatland, Sedge-Sphagnum and Sphagnum-Sedge Types of Peat

(Sample No. 1, 0.6 to 1.2 m; sample No. 2, 1.2 to 1.6 m; sample No. 3, 1.6 to 1.9 m)

Sub-Sample No.	Depth Approx. (cm)	Run No.	Small Tube Volume (mL)	Large Tube Volume (mL)	% Decomposition	% Difference	Average	% Ash	Adjusted % Decomp	Von Post
C2-13	180 - 190	1	0.70	0.15	18.0					
			0.85	0.17	17.5	3.5	19.0	54.9	14.0	H8
			0.80	0.18	19.5					
			0.80	0.20	21.0					
		2	0.72	0.20	23.0					
			0.70	0.20	23.0	6.0	24.0	54.9	19.0	H8
			0.70	0.25	28.0					
			0.90	0.23	22.0					

Contd..

DEGREE OF DECOMPOSITION TEST RESULTS - New York State Peat Sample, Folley Bog 1 and 2, Lowmoor Peatlands, Wood-Sedge and Sedge-Sphagnum Type of Peat

Sample No.	Depth Approx. (cm)	Run No.	Small Tube Volume (mL)	Large Tube Volume (mL)	% Decomposition	% Difference	Average	% Ash	Adjusted % Decomp	Von Post
1 (Bog No. 2)	0 - 350	1	1.0	0.21	19.0					
			0.85	0.20	21.0	2.0	20.0	1.7	20.0	H5-H6
			0.80	0.20	21.0					
			0.79	0.17	19.0					
		2	1.10	0.22	18.0					
			1.05	0.22	19.0	3.0	19.5	1.7	19.5	H5-H6
			0.98	0.24	21.0					
			0.95	0.23	21.0					
2 (Bog No. 1)	0 - 350	1	1.0	0.24	21.0					
			0.95	0.26	24.0	4.0	21.8	2.7	21.8	H5-H6
			0.75	0.20	22.0					
			0.90	0.20	20.0					
		2	0.96	0.23	21.0					
			1.10	0.22	18.0	4.0	18.9	2.7	18.9	H5-H6
			0.85	0.20	17.0					
			0.99	0.21	19.0					
3 (Bog No. 1)	0 - 20	---------- UNABLE TO PERFORM TEST (Surface Layer) ----------								

Contd....

DEGREE OF DECOMPOSITION TEST RESULTS - New York State Peat Sample - Fort Drum, Lowmoor Peatlands, Wood-Sedge and Sedge-Sphagnum Type of Peat

Sample No.	Depth Approx. (cm)	Run No.	Small Tube Volume (mL)	Large Tube Volume (mL)	% Decomposition	% Difference	Average	% Ash	Adjusted % Decomp	Von Post
4	0 - 50 (Surface Layer)	1	1.30	0.18	13.5					
			1.20	0.14	12.0	4.0	13.4	2.6	13.4	H4
			1.10	0.13	12.0					
			0.95	0.16	16.0					
		2	1.00	0.12	12.5					
			1.10	0.15	13.0	1.5	13.1	2.6	13.1	H4
			0.95	0.14	14.0					
			1.00	0.13	13.0					
5	0 - 50	---	----------	----------	---------- UNABLE TO PERFORM TEST (Surface Layer) ----------					
6	0 - 350	1	1.05	0.25	22.0					
			0.90	0.25	24.0	3.0	23.8	15.7	21.8	H7-H8
			0.95	0.27	25.0					
			0.90	0.25	24.0					
		2	1.10	0.30	25.0					
			1.00	0.29	25.0	1.0	24.8	15.7	22.8	H7-H8
			0.98	0.29	25.0					
			0.95	0.26	24.0					

Contd....

DEGREE OF DECOMPOSITION TEST RESULTS - New York State Peat Sample, Bog JJ4-2, Lowmoor Peatlands, Sedge-Sphagnum Type of Peat

Sample No.	Depth Approx. (cm)	Run No.	Small Tube Volume (mL)	Large Tube Volume (mL)	% Decomposition	% Difference	Average	% Ash	Adjusted % Decomp	Von Post
7	0 - 300	1	0.90	0.25	24.0					
			0.86	0.21	21.5	4.0	22.9	14.3	22.9	H6-H7
			0.90	0.20	21.0					
			0.85	0.25	25.0					
		2	1.00	0.23	21.0					
			0.99	0.24	22.0	1.0	21.5	14.3	21.5	H6-H7
			0.89	0.21	21.0					
			0.95	0.23	22.0					

Contd..

DEGREE OF DECOMPOSITION TEST RESULTS - Inkerman Ferry (New Brunswick) Peat Samples, Highmoor Peatland, Sphagnum Medium and Sphagnum (Mixed) Peat Types

Sample No.	Depth Approx. (cm)	Run No.	Small Tube Volume (mL)	Large Tube Volume (mL)	% Decomposition	% Difference	Average	% Ash	Adjusted % Decomp	Von Post
NB-1		1	1.0	0.13	10.0					
			0.9	0.10	9.0	1.0	9.25	1.0	9.25	H4
			1.2	0.12	9.0					
			1.0	0.11	9.0					
NB-2			---------- UNABLE TO PERFORM TEST ----------					2.5		
NB-3	0 - 100	1	1.2	0.14	10.0					
			1.0	0.15	12.0	3.0	10.5	0.6	10.5	H4
			0.9	0.10	9.0					
			0.9	0.12	11.0					
NB-4	100 - 350	1	0.80	0.10	11.0					
			1.10	0.14	13.0	2.0	11.5	1.1	11.5	H4
			0.75	0.11	11.0					
			1.00	0.12	11.0					
NB-5	350 - 450	1	0.95	0.15	12.0					
			1.10	0.15	11.0	2.0	11.0	3.0	11.0	H5-H6
			1.10	0.14	11.0					
			1.00	0.11	10.0					
NB-6	450 - 550	1	1.10	0.16	12.0					
			1.00	0.16	15.0	3.0	14.0	3.0	14.0	H7
			1.00	0.17	15.0					
			0.90	0.15	14.0					

Contd..

DEGREE OF DECOMPOSITION TEST RESULTS - Deschambault Lake (Saskatchewan) Peat Samples, Transitional Moor/ Lowmoor Peatland Sedge-Sphagnum Type of Peat

Sample No.	Depth Approx. (cm)	Run No.	Small Tube Volume (mL)	Large Tube Volume (mL)	% Decomposition	% Difference	Average	% Ash	Adjusted % Decomp	Von Post
1	50 - 100	1	1.0	0.15	11.0					
			0.9	0.14	13.0	3.0	12.5	7.2	12.5	H3-H4
			0.8	0.13	12.0					
			1.0	0.16	14.0					
2	100 - 150	1	0.80	0.13	13.0					
			1.10	0.15	12.0	2.0	12.25	6.5	12.25	H5
			0.95	0.14	13.0					
			1.00	0.14	11.0					
3	150 - 200	1	1.1	0.16	12.0					
			1.1	0.18	15.0	4.0	13.75	7.0	13.75	H4-H5
			1.0	0.20	16.0					
			1.2	0.18	12.0					

APPENDIX C

CALIBRATION GRAPHS FOR THE THOMAS-STORMER VISCOMETER

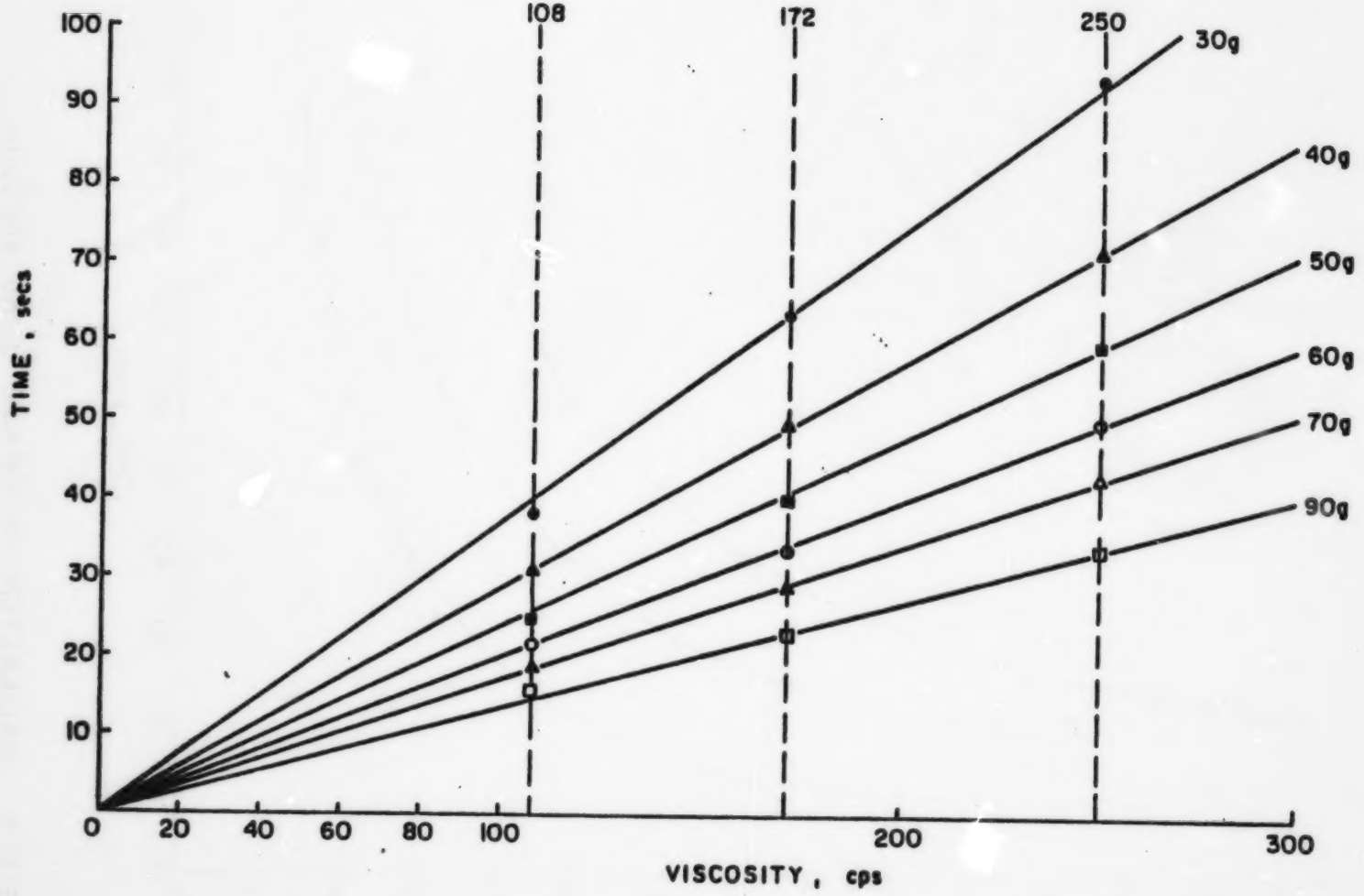


FIGURE C-1 CALIBRATION GRAPH No.1 USING AQUEOUS GLYCEROL SOLUTIONS.

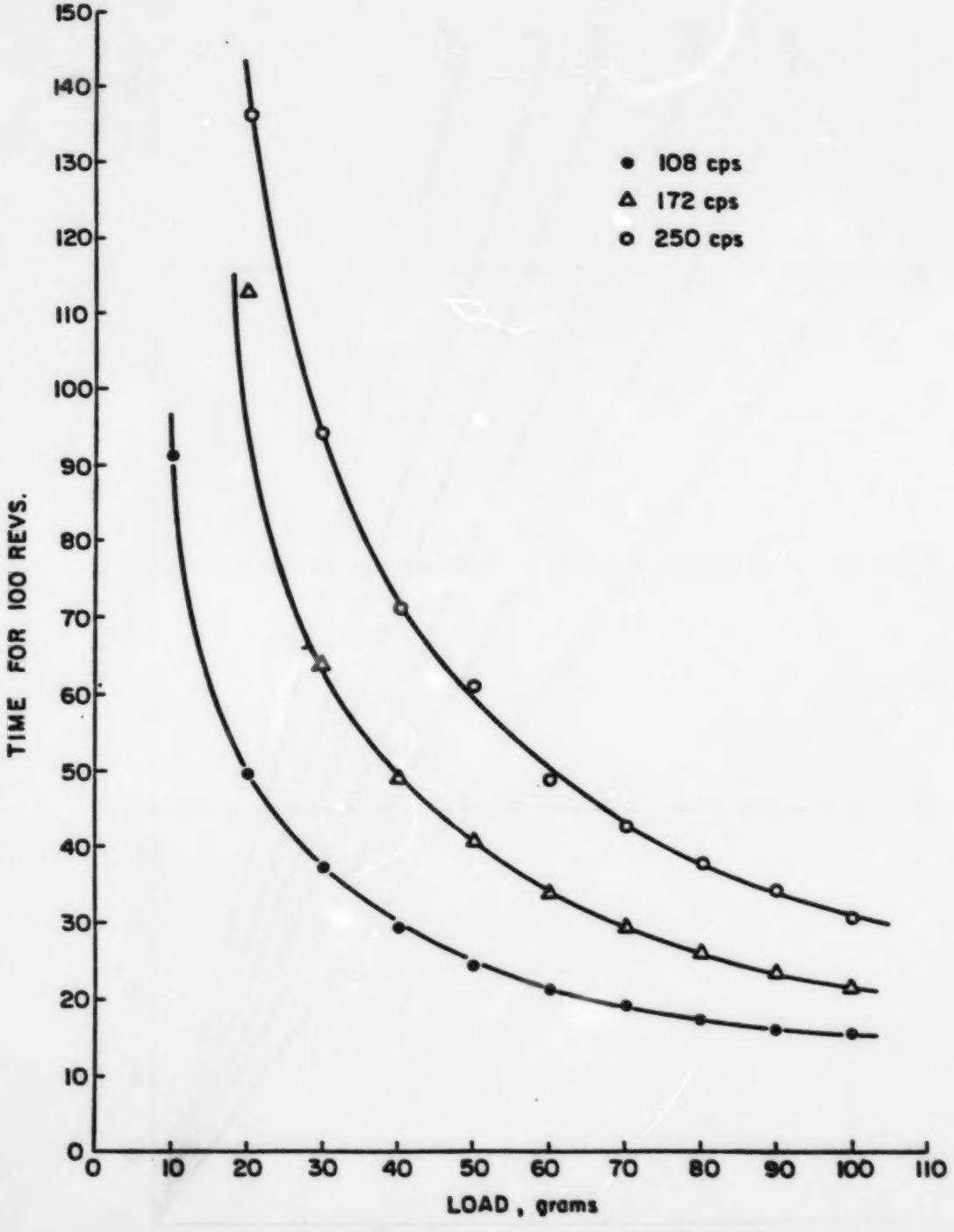


FIGURE C-2 CALIBRATION GRAPH No. 2 USING AQUEOUS GLYCEROL SOLUTIONS.

APPENDIX D

THOMAS-STORMER TEST PROCEDURE

OPERATING INSTRUCTIONS

9730-F10 Thomas-Stormer Viscometer

Reference: Arthur H. Thomas Co., Philadelphia, PA 19105, USA

The Stormer Viscometer with its various accessories can be employed for determining viscosities of a great variety of materials and products. The following instructions for the General Purpose Outfit apply generally to all modifications of the instrument.

TEST PROCEDURE (Refer to Fig. 3-2 for the following procedure)

1. Place the instrument on a horizontal shelf or table so that the driving weight can drop without obstruction through a distance of approximately 40 inches. This will allow the rotor to make about 125 revolutions, as indicated by the pointer on the revolution counter, each graduation representing one revolution of the rotor. Position of pulley bracket which, in the current model, is clamped to the dust cap of the center spindle, can be changed to permit driving weight to fall either directly in front of or to the right end of the table or shelf, as desired, the dial remaining in front of operator for convenient reading. This is accomplished by twisting and sliding off, as a unit, the pulley bracket and the dust cap, which latter is attached to the center spindle housing by friction fit. Place the bracket in the

desired position; lift pulley arm up, slide back until notch engages pin, and tighten set screw to hold. Make certain the dust cap is pushed all the way up on the center spindle housing.

2. Attach the rotor by pushing its stem upward as far as possible into the chuck and securing it with the knurled set screw on the chuck.

> NOTE: Due to the difference in tolerances between the rotor shaft and the chuck, it is possible in some combinations for the rotor to show a slight eccentric action when revolving in air. This should be minimized by turning the rotor shaft slightly in the chuck until the optimum point is found. A file mark should then be made on the rotor shaft at a point below the center of the knurled set screw. The rotor should thereafter be kept in this position for all tests.

3. Place water or oil bath on movable platform, loosening the bath adjusting screws if necessary. Place the test cup in position in the bath, as shown by dotted lines in Figure 4.1, with the stop plate on the side of the cup engaging one of the projecting arms in the bath. This will prevent the test cup from rotating within the bath. If cup is equipped with thermometer holder, place holder to the left when facing the dial.

4. Loosen the platform set screw and raise platform to the stop on the vertical support. Secure the platform in this position by tightening the set screw.

5. Center the bath containing the cup (or other container, as for corn or paint) by adjusting the set screws in the rim of the platform. The rotor, when lowered, should be concentric with the rim of the test

cup, or other container, with equal space between each side vane and rotor, thereby permitting the rotor to turn freely without touching the side vanes at any point.

6. Run the cord over the pulley and rewind to insure uniform winding on the drum. If pulley bracket has been pushed up on the dust cap as far as it will go and tightened in place, as directed in paragraph 1, the cord will travel smoothly down the winding drum in one even layer without overlapping. Turn handle on winding drum counter-clockwise to rewind. Brake is set or released by a quarter turn of the brake control knob.

NOTE: A spring under the rewind drum permits rewinding when the brake is "on" without moving the rotor or the revolution counter.

7. Lower the platform holding the bath and test cup, being sure the thermometer, rotor and test cup used are clean and dry.

8. Remove the test cup, fill with test sample to 1/4 inch above the side vanes, and replace it in the bath as directed in paragraph 3.

9. Fill the bath with water or oil, depending upon the temperature at which the sample is to be maintained, oil being used for higher temperatures.

Do not operate the bath at a temperature high enough to volatilize the test sample because the vapors will condense on the moving parts and interfere with their proper functioning. Solder is used in the construction of test cups and rotors; therefore, temperatures over 148°C (300°F) - the melting point of the solder - will damage these parts.

10. Raise the platform with bath and test cup until the contents of the cup cover the rotor to a depth of 1/4 inch. Secure the platform in this position by tightening the platform set screw. The stop on the vertical support should be set to determine this position for subsequent tests, as the rotor must be immersed to the same depth for each succeeding reading to insure consistent results.

11. Place the thermometer in the holder.

12. Obtain the desired temperature of the liquid under test by heating the bath with a burner or thermostatically controlled electric heater, or by cooling with cracked ice, observing the temperature limitations in warning in paragraph 9. To insure uniformity, stir the sample immediately before taking the temperature preceding the test run. Sufficient time must elapse after changing the temperature of the bath to permit the entire assembly, i.e., bath, test cup and contents, to become equalized. The necessity for accurate temperature control cannot be overemphasized.

13. With the brake "on", raise the driving weight by turning the handle of the rewinding drum counter-clockwise until the weight nearly touches the pulley.

> NOTE: Brake is not designed to support heavy weights, therefore it is recommended that, if heavy weights are required, they be attached after the rotor has been immersed in test sample, immediately before each test run, and detached before sample is lowered from the rotor.

14. Set the dial by releasing the brake by a quarter turn of the brake control knob, allowing rotor to revolve until the pointer on the dial is located between 80 and 90; then set the brake. The purpose of

locating the pointer 10 to 20 graduations to the right of zero is to permit the rotor to turn a sufficient number of revolutions to get a running start before checking with stopwatch. If setting of the dial has caused an appreciable lowering of the weight, again rewind the drum to raise the weight box to the pulley.

15. With stopwatch in hand, release brake and measure the time in seconds required for 100 revolutions of the rotor as indicated by the revolution counter. Set the brake. If the result obtained is less than 20 seconds - a minimum time of 20 seconds is set to avoid turbulence - adjust the driving weight by removing shot from the weight box. If the movement of the rotor is very slow, the driving weight should be increased until a convenient speed is reached for the test.

16. With the stopwatch ready, the dial pointer set between 80 and 90, and the temperature of the sample correctly adjusted, release the brake and start the watch exactly when the pointer passes zero on the revolution counter. Stop it exactly when the pointer again passes zero, thereby registering the time of 100 revolutions of the rotor.

17. The average of several readings should be taken. Subsequent readings can be made on the same sample by rewinding the cord on the drum, which acts independently of the gear wheel when brake is set. Before each successive reading, the rotor should again be permitted to turn 10 to 20 revolutions before starting the stopwatch. After several practice runs, the operator will acquire the ability to start and stop the watch at exactly the point on the dial which indicates 100 revolutions of the rotor.

CARE OF THE INSTRUMENT

1. Thoroughly clean and dry the instrument and all parts such as rotor, test cup, etc., immediately after use. The cover provided for the gear and pinion prevents easy access of dust. It is impossible, however, to prevent some dust from entering, due largely to changes in room temperature. Comparatively small amounts of dust deposits on the teeth of the gears may produce friction or may cause the instrument to stick. It is recommended that the top of the gear casing be taken off occasionally to inspect the gears, removing carefully any dust which may have accumulated. Care should be taken to protect the gear wheel against mechanical injury, such as bending.

2. Do not oil bearings, gear wheels, counter hand or pulley. Oil may gum, causing dust to collect on these parts, which must be kept clean and dry. These parts are delicate and the gear ratio very high; consequently, oil would introduce a relatively high friction.

3. Do not touch the dial pointer or try to make any adjustment on it, since the revolution counter is a delicate assembly and can easily be thrown out of adjustment.

4. The braking mechanism operates through contact of leather against the lower surface of the large gear. If this leather contact surface becomes glazed through long wear, it can be restored to its original condition by rubbing lightly with sandpaper. When worn out, it should be renewed. To accomplish this, it is necessary to remove the brake assembly. First, lower the driving weight and place it in the weight box holder to relive tension on large gear. Then loosen the brake assembly set screw at side of gear casing and lift out the brake

assembly. When removing the glaze, make sure the leather surface is left smooth and even. Before replacing the brake assembly, remove the top cover of the gear casing, exposing the large gear wheel. Then insert the brake assembly in its mounting hole and bring it into position so that, when brake is released, the leather surface will not touch the wheel. Replace the cover of the gear casing.

APPENDIX E

VISCOSITY - ORF LABORATORY TEST RESULTS

ONTARIO PEAT

SIZE (MM)	SLURRY (% SOLIDS)	TEMP (C)	LOAD P (GRAMS)	TIME (SECS)	APP VISC, nPER (CPS)	VEL Vr (CM/SEC)
SAMPLE 1						
4.00	2.80	10.00	9.00	55.00	41.95	18.14
			14.00	45.90	54.46	21.73
			18.00	30.00	45.76	33.25
			24.00	23.70	48.20	42.09
			29.00	21.70	53.33	45.97
4.00	2.80	20.00	9.00	59.10	45.08	16.89
			14.00	33.60	39.86	29.69
			16.00	30.90	41.90	32.28
			18.00	26.50	40.42	37.64
			24.00	20.50	41.69	48.66
4.00	3.30	0.00	14.00	67.90	80.56	14.69
			19.00	44.30	71.33	22.52
			24.00	36.00	73.22	27.71
			29.00	27.60	67.83	36.14
			34.00	23.70	68.29	42.09
4.00	3.30	15.00	14.00	43.20	51.25	23.09
			19.00	33.00	53.14	30.23
			24.00	27.20	55.32	36.67
			29.00	24.90	61.19	40.06
			34.00	21.10	60.80	47.27
4.00	3.60	10.00	14.50	54.00	66.36	18.47
			19.50	36.10	59.66	27.63
			24.50	29.30	60.83	34.04
			29.50	24.70	61.75	40.38
			34.50	21.70	63.44	45.97
4.00	3.60	20.00	14.50	47.70	58.61	20.91
			19.50	32.30	53.38	30.88
			24.50	26.80	55.64	37.22
			29.50	23.10	57.75	43.19
			34.50	20.00	58.47	49.88
4.00	3.90	0.00	24.50	53.30	110.67	18.71
			34.50	37.80	110.52	26.39
			39.50	32.70	109.46	30.50
			44.50	26.20	98.81	38.07
			49.50	22.80	95.64	43.75
4.00	3.90	15.00	19.50	39.10	64.61	25.51
			24.50	31.20	64.78	31.97
			29.50	26.40	66.00	37.78
			34.50	23.00	67.25	43.37
			39.50	20.70	69.29	48.19

7.00	2.80	20.00	14.50	38.60	47.43	25.84
			19.50	30.20	49.91	33.03
			24.50	25.10	52.11	39.74
			29.50	20.80	52.00	47.96
7.00	3.60	10.00	34.50	53.20	155.54	18.75
			44.50	36.20	136.52	27.56
			50.00	22.00	93.22	45.34
			60.00	20.80	105.76	47.96
7.00	3.60	20.00	34.50	39.40	115.19	25.32
			39.50	27.30	91.39	36.54
			44.50	23.20	87.49	43.00
			49.50	20.30	85.16	49.14
7.00	4.20	10.00	50.00	45.80	194.07	21.78
			60.00	33.50	170.34	29.78
			70.00	24.90	147.71	40.06
			80.00	21.00	142.37	47.50
7.00	4.20	20.00	34.50	56.30	164.61	17.72
			44.50	33.00	124.45	30.23
			50.00	37.80	160.17	26.39
			60.00	22.50	114.41	44.33
SAMPLE I						
7.00	2.80	10.00	9.50	57.80	46.53	17.26
			14.50	38.80	47.68	25.71
			19.50	31.70	52.39	31.47
			24.50	25.50	52.94	39.12
			29.50	21.70	54.25	45.97
7.00		20.00	9.50	47.60	38.32	20.96
			14.50	33.60	41.29	29.69
			19.50	26.60	43.96	37.50
			24.50	22.10	45.89	45.14
			26.50	21.00	47.16	47.50
7.00	3.30	0.00	24.50	66.40	137.86	15.02
			29.50	57.40	143.50	17.38
			34.50	46.90	137.12	21.27
			44.50	31.80	119.92	31.37
			50.00	26.20	111.02	38.07
7.00	3.30	15.00	14.50	52.00	63.90	19.18
			19.50	35.20	58.17	28.34
			24.50	27.60	57.31	36.14
			29.50	24.20	60.50	41.22
			34.50	21.00	61.40	47.50
7.00	3.60	10.00	24.50	57.00	118.35	17.50
			34.50	45.00	131.57	22.17

			49.50	34.00	142.63	29.34
			50.00	28.40	120.34	35.12
			55.00	23.30	108.60	42.81
			60.00	20.50	104.24	48.66
4.00	4.20	20.00	44.50	42.80	161.41	23.31
			49.50	32.30	135.50	30.88
			50.00	28.10	119.07	35.50
			55.00	23.50	109.53	42.45
			60.00	20.50	104.24	48.66
SAMPLE 2						
4.00	2.80	10.00	14.50	43.30	53.21	23.04
			19.50	33.10	54.70	30.14
			24.50	28.00	58.14	35.63
			29.50	23.20	58.00	43.00
			34.50	20.90	61.11	47.73
4.00	2.80	20.00	9.50	46.00	37.03	21.68
			14.50	36.10	44.36	27.63
			19.50	27.40	45.28	36.41
			24.50	22.00	45.68	45.34
			29.50	20.50	51.25	48.66
4.00	3.60	10.00	24.50	39.50	82.01	25.25
			29.50	33.20	83.00	30.05
			34.50	26.00	76.02	38.37
			39.50	24.10	80.67	41.39
			44.50	20.60	77.69	48.42
4.00	3.60	20.00	14.50	45.00	55.30	22.17
			19.50	35.30	58.33	28.26
			24.50	28.90	60.00	34.52
			29.50	24.90	62.25	40.06
			34.50	21.40	62.57	46.61
4.00	4.20	10.00	29.50	45.20	113.00	22.07
			34.50	33.50	97.94	29.78
			39.50	30.40	101.76	32.81
			44.50	26.80	101.07	37.22
			49.50	23.30	97.74	42.81
4.00	4.20	20.00	24.50	51.10	106.10	19.52
			29.50	35.00	87.50	28.50
			34.50	27.40	80.11	36.41
			39.50	24.80	83.02	40.22
			44.50	20.90	78.82	47.73
SAMPLE 2						
7.00	2.80	10.00	14.50	45.20	55.54	22.07
			19.50	36.30	59.99	27.48
			24.50	28.70	59.59	34.76
			29.50	24.50	61.25	40.71

			44.50	28.40	107.10	35.12
			49.50	22.60	94.81	44.14
7.00	3.60	20.00	24.50	51.70	107.34	19.29
			29.50	33.50	83.75	29.78
			34.50	29.10	85.08	34.28
			39.50	24.30	81.34	41.05
			44.50	20.80	78.44	47.96
7.00	3.90	0.00	34.50	42.70	124.84	23.36
			39.50	34.40	115.15	29.00
			44.50	29.70	112.00	33.59
			49.50	26.80	112.42	37.22
			50.00	23.00	97.46	43.37
7.00	3.90	15.00	24.50	45.90	95.30	21.73
			34.50	32.20	94.14	30.98
			39.50	27.70	92.72	36.01
			44.50	23.90	90.13	41.74
7.00	4.20	10.00	50.00	41.20	174.58	24.21
			55.00	31.00	144.49	32.18
			60.00	29.00	147.46	34.40
			65.00	26.00	143.22	38.37
			70.00	20.60	122.20	48.42
7.00	4.20	20.00	44.50	50.40	190.07	19.79
			49.50	36.40	152.69	27.40
			50.00	32.50	137.71	30.69
			55.00	26.10	121.65	38.22
			60.00	21.90	111.36	45.55
SAMPLE 3						
4.00	2.80	0.00	14.50	42.40	52.10	23.53
			19.50	31.50	52.06	31.67
			24.50	23.50	48.79	42.45
			29.50	20.70	51.75	48.19
4.00	2.80	10.00	9.50	46.10	37.11	21.64
			14.50	36.60	44.97	27.25
			19.50	26.70	44.12	37.36
			24.50	21.70	45.06	45.97
4.00	2.80	20.00	9.50	43.40	34.94	22.98
			14.50	30.50	37.48	32.70
			19.50	21.90	36.19	45.55
4.00	4.20	0.00	44.50	44.20	166.69	22.57
			49.50	37.00	155.21	26.96
			50.00	28.40	120.34	35.12
			60.00	23.90	121.53	41.74
			65.00	20.10	110.72	49.63

			19.50	35.00	57.84	28.50
			24.50	24.40	50.66	40.86
			29.50	21.70	54.25	45.97
4.00	4.20	20.00	14.50	40.40	49.64	24.69
			19.50	27.50	45.44	36.27
			24.50	21.70	45.06	45.97
7.00	2.80	0.00	14.50	37.40	45.96	26.67
			19.50	29.40	48.58	33.93
			24.50	23.20	48.17	43.00
			29.50	20.60	51.50	48.42
7.00	2.80	10.00	9.50	53.00	42.67	18.82
			14.50	34.00	41.78	29.34
			19.50	27.50	45.44	36.27
			24.50	22.30	46.30	44.73
7.00	2.80	20.00	9.50	45.30	36.47	22.02
			14.50	33.00	40.55	30.23
			19.50	26.80	44.29	37.22
			24.50	20.60	42.77	48.42
7.00	4.20	0.00	44.50	45.70	172.34	21.83
			49.50	41.20	172.83	24.21
			50.00	38.50	163.14	25.91
			55.00	34.50	160.81	28.91
			60.00	22.90	116.44	43.56
7.00	4.20	10.00	34.50	46.00	134.49	21.68
			39.50	34.40	115.15	29.00
			44.50	25.80	97.30	38.66
			49.50	21.10	88.51	47.27
7.00	4.20	20.00	29.50	44.70	111.75	22.32
			34.50	32.60	95.31	30.60
			39.50	25.60	85.69	38.96
			44.50	20.90	78.82	47.73

NEW YORK PEAT

SIZE (MM)	SLURRY (% SLURRY)	TEMP (C)	LOAD P (GRAMS)	TIME (SECS)	APP VISC,nPER VEL Vr (CPS)	(CM/SEC)
SAMPLE 1						
4.00	2.80	10.00	11.50	121.10	118.02	8.24
			12.50	109.20	115.68	9.13
			14.50	53.00	65.13	18.82
			24.50	36.60	75.99	27.25
			34.50	21.90	64.03	45.55
4.00	2.80	20.00	9.50	96.30	77.53	10.36
			10.50	74.90	66.65	13.32
			11.50	58.80	57.31	16.96
			14.50	38.20	46.94	26.11
			24.50	24.70	51.28	40.38
4.00	3.30	1.00	19.50	127.40	210.53	7.83
			21.50	97.50	177.65	10.23
			24.50	72.90	151.36	13.68
			34.50	35.50	103.79	28.10
			54.50	20.50	94.68	48.66
4.00	3.30	15.00	14.50	131.00	160.97	7.61
			19.50	78.50	129.72	12.71
			21.50	68.60	124.99	14.54
			24.50	37.90	78.69	26.32
			34.50	22.60	66.08	44.14
4.00	3.60	10.00	22.50	123.70	235.87	8.06
			24.50	94.80	196.83	10.52
			29.50	74.90	187.25	13.32
			34.50	43.80	128.06	22.77
			54.50	22.30	103.00	44.73
4.00	3.60	20.00	21.50	114.30	208.26	8.73
			24.50	81.40	169.01	12.25
			29.50	55.90	139.75	17.84
			34.50	39.90	116.66	25.00
			44.50	22.80	85.98	43.75
4.00	3.90	1.00	39.50	109.80	367.55	9.08
			44.50	83.60	315.27	11.93
			54.50	55.50	256.33	17.97
			64.50	36.70	200.61	27.18
			74.50	26.00	164.15	38.37
4.00	3.90	15.00	29.50	150.20	375.50	6.64
			34.50	106.20	310.50	9.39
			44.50	50.90	191.95	19.60
			54.50	35.60	164.42	28.02
			64.50	22.50	122.99	44.33

			54.50	67.60	312.22	14.76
			64.50	43.70	238.87	22.83
			74.50	34.60	218.45	28.83
			94.50	22.80	182.59	43.75
4.00	4.20	20.00	44.50	107.10	403.89	9.31
			54.50	84.90	392.12	11.75
			64.50	47.00	256.91	21.22
			74.50	37.20	234.86	26.81
			84.50	23.10	165.42	43.18
SAMPLE 2						
4.00	2.80	10.00	11.50	87.00	84.79	11.47
			12.50	86.00	91.10	11.60
			14.50	63.70	78.28	15.66
			24.50	28.60	59.38	34.88
			34.50	21.30	62.28	46.83
4.00	2.80	20.00	9.50	75.60	60.86	13.19
			10.50	57.80	51.43	17.26
			11.50	51.80	50.48	19.26
			14.50	42.60	52.35	23.42
			24.50	25.30	52.53	39.43
4.00	3.30	1.00	27.50	75.70	176.42	13.18
			29.50	49.30	123.25	20.23
			34.50	39.80	116.36	25.06
			44.50	24.80	93.53	40.22
			54.50	22.40	103.46	44.53
4.00	3.30	15.00	19.50	116.80	193.02	8.54
			22.50	72.80	138.81	13.70
			24.50	46.40	96.34	21.50
			34.50	29.80	87.13	33.47
			44.50	21.90	82.59	45.55
4.00	3.60	10.00	26.50	89.80	201.67	11.11
			29.50	62.80	157.00	15.88
			34.50	56.30	164.61	17.72
			44.50	29.70	112.00	33.59
			54.50	23.60	109.00	42.27
4.00	3.60	20.00	21.50	89.90	163.80	11.10
			24.50	75.80	157.38	13.16
			34.50	36.90	107.89	27.03
			44.50	21.30	80.33	46.83
4.00	3.90	1.00	41.50	92.30	324.61	10.81
			44.50	86.10	324.70	11.59
			54.50	50.30	232.32	19.83
			64.50	41.20	225.20	24.21
			74.50	26.50	167.31	37.64

			54.50	36.30	167.66	27.48
			64.50	28.60	156.33	34.88
4.00	4.20	10.00	44.50	82.00	309.24	12.16
			54.50	60.60	279.89	16.46
			64.50	39.20	208.81	26.11
			74.50	28.90	182.46	34.52
			84.50	21.50	153.96	46.40
4.00	4.20	20.00	39.50	111.00	371.57	8.99
			44.50	86.10	324.70	11.59
			54.50	51.70	238.78	19.29
			64.50	36.10	197.33	27.63
			74.50	24.90	157.21	40.06
SAMPLE 3						
4.00	2.80	10.00	4.50	73.50	28.03	13.57
			5.50	56.10	26.15	17.78
			6.50	50.60	27.87	19.71
			9.50	34.80	28.02	28.66
			14.50	24.50	30.11	40.71
4.00	2.80	20.00	4.50	72.80	27.76	13.70
			6.50	50.40	27.76	19.79
			9.50	38.30	30.83	26.04
			14.50	27.50	33.79	36.27
			17.50	20.00	29.66	49.88
4.00	3.30	1.00	5.50	88.30	41.16	11.30
			8.50	63.20	45.53	15.78
			9.50	53.50	43.07	18.64
			14.50	36.00	44.24	27.71
			24.50	20.00	41.53	49.88
4.00	3.30	15.00	5.50	72.10	33.61	13.83
			8.50	49.80	35.87	20.03
			9.50	42.40	34.14	23.53
			14.50	29.70	36.50	33.59
			19.50	20.30	33.55	49.14
4.00	3.60	10.00	5.50	91.40	42.60	10.91
			8.50	47.80	34.43	20.87
			9.50	39.40	31.72	25.32
			14.50	31.60	38.83	31.57
			19.50	24.70	40.82	40.38
4.00	3.60	20.00	4.50	88.80	33.86	11.23
			6.50	48.80	26.88	20.44
			9.50	42.90	34.54	23.25
			14.50	28.20	34.65	35.37
			19.50	20.20	33.38	49.38

			9.50	52.40	42.19	19.04
			14.50	41.30	50.75	24.15
			24.50	24.50	50.87	40.71
4.00	3.90	15.00	5.50	116.30	54.21	8.58
			7.50	49.90	31.72	19.99
			9.50	43.70	35.18	22.83
			14.50	28.50	35.02	35.00
			19.50	23.30	38.50	42.81
4.00	4.20	10.00	6.50	160.50	88.41	6.21
			7.50	129.60	82.37	7.70
			9.50	50.70	40.82	19.67
			14.50	32.60	40.06	30.60
			24.50	21.60	44.85	46.18
4.00	4.20	20.00	4.50	133.20	50.80	7.49
			6.50	83.90	46.22	11.89
			9.50	48.20	38.81	20.70
			14.50	31.00	38.09	32.18
			19.50	27.70	45.78	36.01
SAMPLE 4						
4.00	2.80	10.00	7.50	140.20	89.11	7.11
			8.50	87.60	63.10	11.39
			11.50	55.70	54.28	17.91
			14.50	45.50	55.91	21.92
			24.50	23.20	48.17	43.00
4.00	2.80	20.00	7.50	112.20	71.31	8.89
			9.50	53.70	43.23	18.58
			11.50	52.60	51.26	18.96
			14.50	36.80	45.22	27.11
			24.50	20.60	42.77	48.42
4.00	3.30	1.00	19.50	65.90	108.90	15.14
			21.50	50.80	92.56	19.64
			24.50	47.30	98.21	21.09
			34.50	34.80	101.75	28.66
			44.50	22.80	85.98	43.75
4.00	3.30	15.00	12.50	139.10	147.35	7.17
			14.50	84.30	103.59	11.83
			19.50	35.30	58.33	28.26
			24.50	33.50	69.56	29.78
			34.50	21.60	63.15	46.18
4.00	3.60	10.00	18.50	65.10	102.06	15.32
			19.50	59.50	98.33	16.76
			21.50	56.40	102.76	17.69
			24.50	46.70	96.96	21.36
			34.50	26.60	77.77	37.50

			19.50	79.80	131.87	12.50
			24.50	40.20	83.47	24.81
			34.50	21.40	62.57	46.61
4.00	3.90	1.00	39.50	64.00	214.24	15.59
			44.50	49.80	187.81	20.03
			54.50	40.30	196.13	24.75
			64.50	26.60	145.40	37.50
			74.50	21.20	133.85	47.05
4.00	3.90	15.00	19.50	123.50	204.09	8.08
			24.50	68.40	142.02	14.58
			29.50	48.60	121.50	20.52
			34.50	38.40	112.27	25.98
			44.50	21.70	81.83	45.97
4.00	4.20	10.00	34.50	77.80	227.47	12.82
			39.50	52.30	175.07	19.07
			44.50	44.50	167.82	22.42
			54.50	33.80	156.11	29.51
			64.50	20.40	111.51	48.90
4.00	4.20	20.00	29.50	105.30	263.25	9.47
			34.50	78.20	228.64	12.76
			44.50	42.10	158.77	23.69
			54.50	28.10	129.78	35.50
SAMPLE 5						
4.00	2.80	10.00	4.50	58.80	22.42	16.96
			5.50	50.10	23.35	19.91
			7.50	33.00	20.97	30.23
			9.50	29.00	23.35	34.40
			14.50	21.60	26.54	46.18
4.00	2.80	20.00	4.50	52.00	19.83	19.18
			5.50	37.50	17.48	26.60
			6.50	32.90	18.12	30.32
			9.50	25.60	20.61	38.96
			14.50	19.60	24.08	50.89

SIZE (MM)	SLURRY (% SLURRY)	TEMP (C)	LOAD P (GRAMS)	TIME (SECS)	CON VISC,nPER VEL Vr (CPS)	(CM/SEC)
4.00	3.30	1.00	4.50	81.60	31.12	12.22
			5.50	72.50	33.79	13.76
			7.50	51.00	32.42	19.56
			9.50	43.00	34.62	23.20
			14.50	26.20	32.19	38.07
			24.50	20.00	41.53	49.88
4.00	3.30	15.00	4.50	109.80	41.87	9.08
			5.50	56.90	26.52	17.53
			7.50	40.80	25.93	24.45
			9.50	34.50	27.78	28.91
			14.50	26.10	32.07	38.22
4.00	3.60	10.00	4.50	74.80	28.53	13.34
			5.50	61.80	28.81	16.14
			7.50	43.50	27.65	22.93
			9.50	34.30	27.61	29.08
			14.50	24.80	30.47	40.22
4.00	3.60	20.00	4.50	56.20	21.43	17.75
			5.50	45.00	20.97	22.17
			7.50	34.80	22.12	28.66
			9.50	31.40	25.28	31.77
			14.50	22.30	27.40	44.73
4.00	3.90	1.00	7.50	60.10	38.20	16.60
			9.50	46.50	37.44	21.45
			10.50	32.00	28.47	31.17
			19.50	29.30	48.42	34.04
			24.50	23.60	49.00	42.27
4.00	3.90	15.00	4.50	89.20	34.02	11.18
			5.50	67.50	31.46	14.78
			7.50	49.50	31.46	20.15
			9.50	35.60	28.66	28.02
			14.50	24.90	30.60	40.06
4.00	4.20	10.00	5.50	78.70	36.68	12.67
			7.50	52.80	33.56	18.89
			9.50	45.40	36.55	21.97
			14.50	26.20	32.19	38.07
			19.50	22.10	36.52	45.14
4.00	4.20	20.00	4.50	109.90	41.91	9.08
			5.50	75.20	35.05	13.26
			7.50	39.00	24.79	25.58
			9.50	34.40	27.69	29.00

4.00	2.80	10.00	4.50	79.00	30.13	12.63
			5.50	69.70	32.49	14.31
			7.50	41.90	26.63	23.81
			9.50	36.40	29.31	27.40
			14.50	26.40	32.44	37.78
4.00	2.80	20.00	4.50	71.30	27.19	13.99
			5.50	61.70	28.76	16.17
			7.50	41.90	26.63	23.81
			9.50	29.20	23.51	34.16
			14.50	22.50	27.65	44.33
4.00	3.30	1.00	7.50	60.30	38.33	16.54
			9.50	41.70	33.57	23.92
			14.50	29.30	36.00	34.04
			19.50	22.60	37.35	44.14
4.00	3.30	15.00	6.50	56.90	31.34	17.53
			7.50	45.80	29.11	21.78
			9.50	44.10	35.50	22.62
			14.50	27.90	34.28	35.75
4.00	3.60	10.00	5.50	95.20	44.37	10.48
			7.50	58.60	37.25	17.02
			9.50	54.10	43.56	18.44
			14.50	37.00	45.47	26.96
			19.50	22.60	37.35	44.14
4.00	3.60	20.00	6.50	80.50	44.34	12.39
			7.50	61.50	39.09	16.22
			9.50	43.40	34.94	22.98
			14.50	29.80	36.62	33.47
			19.50	22.10	36.52	45.14
4.00	3.90	1.00	11.50	60.60	59.06	16.46
			12.50	51.00	54.03	19.56
			14.50	39.80	48.91	25.06
			19.50	30.30	50.07	32.92
			24.50	24.40	50.66	40.88
4.00	3.90	15.00	9.50	95.00	76.48	10.50
			11.50	41.60	40.54	23.98
			14.50	32.50	39.94	30.69
			19.50	24.30	40.16	41.05
4.00	4.20	10.00	9.50	83.20	66.98	11.99
			14.50	52.10	64.02	19.15
			19.50	29.50	48.75	33.81
			24.50	24.80	51.49	40.22
4.00	4.20	20.00	8.50	100.60	72.47	9.92
			9.50	74.30	59.82	13.43

			24.50	21.20	44.02	47.05
SAMPLE 7						
4.00	2.80	10.00	4.50	85.90	32.76	11.61
			5.50	67.60	31.51	14.76
			7.50	45.90	29.17	21.73
			9.50	33.60	27.05	29.69
			14.50	22.90	28.14	43.56
4.00	2.80	20.00	4.50	62.10	23.68	16.06
			5.50	44.60	20.79	22.37
			7.50	40.50	25.74	24.63
			9.50	32.10	25.84	31.07
			14.50	22.10	27.16	45.14
4.00	3.30	1.00	7.50	76.10	48.37	13.11
			8.50	54.90	39.55	18.17
			9.50	44.40	35.75	22.47
			14.50	36.50	44.85	27.33
			24.50	20.80	43.19	47.96
4.00	3.30	15.00	5.50	82.70	38.55	12.06
			6.50	52.10	28.70	19.15
			7.50	45.70	29.05	21.83
			9.50	33.80	27.21	29.51
			14.50	27.50	33.79	36.27
4.00	3.60	10.00	7.50	52.30	33.24	19.07
			9.50	50.80	40.90	19.64
			11.50	39.60	38.59	25.19
			14.50	32.10	39.44	31.07
			19.50	21.20	35.03	47.05
4.00	3.60	20.00	5.50	70.10	32.67	14.23
			7.50	53.80	34.19	18.54
			9.50	41.30	33.25	24.15
			14.50	31.80	39.08	31.37
			19.50	20.40	33.71	49.90
4.00	3.90	1.00	8.50	104.20	75.06	9.57
			9.50	64.70	52.09	15.42
			11.50	52.80	51.46	18.89
			14.50	38.00	46.69	26.25
			24.50	24.40	50.66	40.88
4.00	3.90	15.00	5.50	78.40	36.54	12.72
			6.50	62.10	34.21	16.06
			7.50	51.20	32.54	19.48
			9.50	47.10	37.92	21.18
			14.50	29.70	36.50	33.59
4.00	4.20	10.00	9.50	77.20	62.15	12.92

			14.50	44.70	54.93	22.32
			19.50	31.10	51.39	32.07
			24.50	21.00	43.60	47.50
4.00	4.20	20.00	7.50	83.30	52.94	11.97
			9.50	60.20	48.47	16.57
			11.50	44.80	43.66	22.27
			14.50	30.10	36.99	33.14
			24.50	19.30	40.07	51.68

NEW YORK STATE PEAT

SIZE (MM)	SLURRY (% SOLIDS)	TEMP (C)	LOAD P (GRAMS)	TIME (SECS)	APP VISC,n (CPS)	PER VEL Vr (CM/SEC)
SAMPLE 1						
7.00	2.80	10.00	6.50	133.00	73.26	7.50
			19.50	34.30	56.68	29.08
			24.50	27.40	56.89	36.41
			29.50	23.30	58.25	42.81
			34.50	20.90	61.11	47.73
7.00	2.80	20.00	6.50	98.20	54.09	10.16
			14.50	36.90	45.34	27.03
			19.50	29.70	49.08	33.59
			24.50	25.10	52.11	39.74
			29.50	21.20	53.00	47.05
7.00	3.30	0.00	14.50	82.40	101.25	12.11
			24.50	57.00	118.35	17.50
			34.50	33.50	97.94	29.78
			44.50	24.10	90.89	41.39
			54.50	22.10	102.07	45.14
7.00	3.30	15.00	14.50	75.80	93.14	13.16
			24.50	40.20	83.47	24.81
			34.50	26.00	76.02	38.37
			44.50	20.70	78.06	48.19
7.00	3.60	10.00	19.50	145.80	240.94	6.84
			29.50	60.70	151.75	16.43
			39.50	38.90	130.22	25.64
			54.50	28.30	130.71	35.25
			59.50	24.20	122.03	41.22
7.00	3.60	20.00	19.50	131.40	217.14	7.59
			29.50	44.70	111.75	22.32
			39.50	31.30	104.78	31.87
			54.90	23.20	107.94	43.00
7.00	3.90	0.00	54.50	83.30	384.73	11.97
			64.50	35.20	192.41	28.34
			74.50	29.10	183.72	34.28
			84.50	22.60	161.84	44.14
7.00	3.90	15.00	44.50	58.70	221.37	16.99
			54.50	42.10	194.44	23.69
			64.50	32.80	179.29	30.41
			74.50	20.60	130.06	48.42
7.00	4.20	10.00	84.50	48.40	346.59	20.61
			94.50	33.00	264.28	30.27
			104.50	27.80	246.19	35.88
			114.50	22.40	217.36	44.53

7.00	4.20	20.00	54.50	60.10	277.58	16.60
			64.50	49.20	268.93	20.27
			74.50	35.60	224.76	28.02
			84.50	29.00	207.67	34.40
			94.50	23.70	189.80	42.09
SAMPLE 2						
7.00	2.80	10.00	11.50	153.00	149.11	6.52
			14.50	109.00	133.94	9.15
			19.50	42.30	69.90	23.58
			24.50	30.80	63.95	32.39
7.00	2.80	20.00	11.50	124.00	120.85	8.04
			14.50	52.50	64.51	19.00
			19.50	32.10	53.05	31.07
			24.50	27.20	56.47	36.67
7.00	3.30	0.00	19.50	84.80	140.14	11.76
			20.50	63.60	110.49	15.68
			21.50	58.30	106.22	17.11
			24.50	47.30	98.21	21.09
			29.50	35.80	89.50	27.86
7.00	3.30	15.00	16.50	70.80	99.00	14.09
			19.50	52.40	86.59	19.04
			24.50	38.50	79.94	25.91
			29.50	26.60	66.50	37.50
7.00	3.60	10.00	29.50	109.10	272.75	9.14
			31.50	63.90	170.58	15.61
			34.50	52.90	154.67	18.86
			39.50	37.40	125.19	26.67
			44.50	30.00	113.14	33.25
7.00	3.60	20.00	24.50	128.20	266.18	7.78
			29.50	63.90	159.75	15.61
			31.50	53.70	143.35	18.58
			34.50	41.60	121.63	23.98
			44.50	24.80	93.53	40.22
7.00	3.90	15.00	44.50	78.70	296.79	12.67
			49.50	46.10	193.39	21.64
			54.50	37.20	171.81	26.61
			59.50	28.30	142.70	35.25
7.00	3.90	0.00	34.50	89.50	261.67	11.15
			39.50	61.60	206.20	16.19
			44.50	49.80	187.81	20.03
			54.50	38.00	175.51	26.25
			59.50	30.00	151.27	33.25
7.00	4.20	20.00	54.50	118.50	547.31	8.42
			59.50	69.30	349.44	14.39

			74.50	42.80	270.22	23.31
			84.50	28.20	201.94	35.37
7.00	4.20	10.00	54.50	74.50	344.09	13.39
			59.50	43.80	220.86	22.77
			64.50	35.20	192.41	28.34
			69.50	31.90	187.89	31.27
			74.50	29.90	188.78	33.36
SAMPLE 3						
7.00	2.80	10.00	5.50	107.70	50.20	9.26
			6.50	85.50	47.10	11.67
			9.50	47.90	38.56	20.82
			14.50	28.80	35.39	34.64
			19.50	23.70	39.17	42.09
7.00	2.80	20.00	4.50	114.80	43.78	8.69
			6.50	52.70	29.03	18.93
			9.50	38.90	31.32	25.64
			11.50	32.70	31.87	30.50
			14.50	26.60	32.69	37.50
7.00	3.30	15.00	6.50	108.30	59.66	9.21
			8.50	86.40	62.24	11.55
			9.50	55.60	44.76	17.94
			14.50	34.80	42.76	28.66
			24.50	24.30	50.45	41.05
7.00	3.30	0.00	7.50	130.90	83.20	7.62
			9.50	64.20	51.69	15.54
			11.50	51.80	50.48	19.26
			14.50	34.80	42.76	28.66
			19.50	29.10	48.09	34.28
			24.50	23.00	47.75	43.37
7.00	3.60	10.00	7.50	139.90	88.92	7.13
			9.50	82.70	66.58	12.06
			12.50	63.90	67.69	15.61
			14.50	42.60	52.35	23.42
			19.50	37.50	61.97	26.60
			24.50	24.40	50.66	40.88
7.00	3.60	20.00	9.50	170.00	136.86	5.87
			11.50	54.50	53.11	18.30
			12.50	41.40	43.86	24.09
			14.50	34.50	42.39	28.91
			24.50	22.40	46.51	44.53
7.00	3.90	0.00	12.50	114.50	121.29	8.71
			14.50	98.70	121.28	10.11
			16.50	94.70	132.42	10.53
			19.50	43.00	71.06	23.20
			24.50	32.50	67.48	30.69

7.00	3.90	15.00	10.50	141.70	126.09	7.04
			12.50	98.70	104.56	10.11
			13.50	80.70	92.33	12.36
			14.50	65.90	80.98	15.14
			24.50	27.40	56.89	36.41
7.00	4.20	10.00	16.50	140.70	196.74	7.09
			18.50	108.90	170.73	9.16
			19.50	78.30	129.39	12.74
			24.50	47.90	99.45	20.82
			34.50	27.00	78.94	36.94
7.00	4.20	20.00	14.50	137.90	169.45	7.23
			15.50	111.20	146.07	8.97
			17.50	92.30	136.89	10.81
			19.50	88.50	146.25	11.27
			24.50	40.80	84.71	24.45
			34.50	23.50	68.71	42.45
SAMPLE 4						
7.00	2.80	10.00	15.50	106.80	140.29	9.34
			16.50	89.80	125.57	11.11
			19.50	62.80	103.78	15.88
			24.50	45.50	94.47	21.92
			34.50	28.10	82.16	35.50
7.00	2.80	20.00	12.50	114.80	121.61	8.69
			14.50	106.70	131.11	9.35
			17.50	51.90	76.97	19.22
			19.50	43.80	72.38	22.77
			24.50	28.70	59.59	34.76
7.00	3.30	0.00	31.50	97.90	261.34	10.19
			34.50	86.40	252.61	11.55
			39.50	60.80	203.53	16.41
			44.50	54.90	207.04	18.17
			54.50	40.70	187.98	24.51
			64.50	24.30	132.83	41.05
7.00	3.30	15.00	24.50	127.90	265.56	7.80
			29.50	88.70	221.75	11.25
			34.50	55.40	161.97	18.01
			39.50	39.80	133.23	25.06
			54.50	21.70	100.22	45.97
7.00	3.60	10.00	34.50	128.40	375.41	7.77
			44.50	81.30	306.60	12.27
			54.50	67.60	312.22	14.76
			64.50	39.30	214.82	25.38
			79.50	24.50	165.06	40.71
7.00	3.60	20.00	34.50	136.70	399.67	7.30
			39.50	80.90	270.81	12.33
			44.50	75.90	286.23	13.14
			54.50	45.10	208.30	22.12

			64.50	28.20	154.14	35.37
7.00	3.90	0.00	44.50	124.90	471.02	7.99
			54.50	95.70	442.00	10.42
			64.50	70.20	383.72	14.21
			74.50	62.30	393.33	16.01
			84.50	41.40	296.47	24.09
			104.50	21.00	185.97	47.50
7.00	3.90	15.00	34.50	134.40	392.95	7.42
			44.50	86.10	324.70	11.59
			54.50	74.20	342.70	13.44
			64.50	42.50	232.31	23.47
			74.50	33.60	212.14	29.69
			84.50	23.20	166.14	43.00
7.00	4.20	10.00	44.50	99.90	376.74	9.98
			54.50	61.40	283.58	16.25
			64.50	41.50	226.84	24.04
			74.50	34.20	215.92	29.17
			94.50	22.20	177.79	44.93
7.00	4.20	20.00	34.50	143.80	420.43	6.94
			44.50	99.00	373.35	10.08
			54.50	64.40	297.44	15.49
			74.50	37.20	234.86	26.81
			84.50	23.40	167.57	42.63

SIZE (MM)	SLURRY (% SOLIDS)	TEMP (C)	LOAD P (GRAMS)	TIME (SECS)	CON VISC (CPS)	nPER VEL Vr (CM/SEC)
SAMPLE 5						
7.00	2.80	10.00	4.50	120.10	45.80	8.31
			5.50	71.30	33.23	12.99
			7.50	47.30	30.06	21.09
			14.50	32.50	39.94	30.69
			19.50	21.80	36.03	45.76
7.00	2.80	20.00	4.50	92.90	35.43	10.74
			5.50	66.60	31.04	14.98
			6.50	51.90	28.59	19.22
			9.50	34.60	27.86	28.83
			14.50	28.00	34.41	35.63
7.00	3.30	0.00	6.50	102.90	56.68	9.69
			8.50	83.00	59.79	12.02
			9.50	61.80	49.75	16.14
			14.50	37.20	45.71	26.81
			24.50	21.80	45.26	45.76
7.00	3.30	15.00	6.50	76.60	42.19	13.02
			7.50	58.50	37.18	17.05
			8.50	40.10	28.89	24.88
			14.50	29.80	36.62	33.47
			24.50	22.30	46.30	44.73
7.00	3.60	10.00	7.50	122.70	77.99	8.13
			9.50	68.30	54.99	14.60
			11.50	43.80	42.69	22.77
			14.50	39.40	48.42	25.32
			19.50	25.30	41.81	39.43
7.00	3.60	20.00	7.50	101.80	64.70	9.80
			8.50	70.80	51.00	14.09
			9.50	67.70	54.50	14.73
			14.50	52.80	64.86	18.89
			19.50	27.70	45.78	36.01
7.00	3.90	0.00	9.50	117.50	94.60	8.49
			10.50	90.80	80.80	10.99
			12.50	61.30	64.94	16.27
			14.50	48.80	59.97	20.44
			24.50	25.80	53.57	38.66
7.00	3.90	15.00	9.50	71.80	57.81	13.89
			10.50	62.80	55.88	15.88
			11.50	46.90	45.71	21.27
			14.50	32.10	39.44	31.07
			24.50	23.90	49.62	41.74

			11.50	87.90	85.67	11.35
			14.50	58.90	72.38	16.94
			19.50	37.40	61.81	26.67
			24.50	25.60	53.15	38.96
7.00	4.20	20.00	10.50	88.50	78.75	11.27
			11.50	80.10	78.06	12.45
			12.50	64.80	68.64	15.39
			14.50	46.20	56.77	21.59
			24.50	31.50	65.40	31.67
			29.50	21.50	53.75	46.40
SAMPLE 6						
7.00	2.80	10.00	4.50	100.30	38.25	9.95
			5.50	79.10	36.87	12.61
			6.50	58.20	32.06	17.14
			9.50	35.60	28.66	28.02
			14.50	25.40	31.21	39.27
7.00	2.80	20.00	4.50	66.50	25.36	15.00
			5.50	55.20	25.73	18.07
			7.50	42.30	26.89	23.58
			14.50	28.70	35.27	34.76
7.00	3.30	0.00	6.50	82.90	45.67	12.03
			9.50	47.60	38.32	20.96
			14.50	41.10	50.50	24.27
			24.50	20.50	42.56	48.66
7.00	3.30	15.00	5.50	81.00	37.75	12.31
			6.60	77.00	43.07	12.95
			7.50	51.10	32.48	19.52
			8.50	42.80	30.83	23.31
			14.50	25.90	31.83	38.51
7.00	3.60	10.00	6.50	97.80	53.87	10.20
			8.50	58.50	42.14	17.05
			9.50	50.10	40.33	19.91
			14.50	32.70	40.18	30.50
			19.50	27.90	46.11	35.75
7.00	3.60	20.00	5.50	92.00	42.88	10.84
			6.50	80.00	44.07	12.47
			7.50	58.90	37.44	16.94
			9.50	42.80	34.46	23.31
			14.50	29.50	36.25	33.91
			24.50	21.80	45.26	45.76
7.00	3.90	0.00	9.50	88.30	71.09	11.30
			10.50	61.60	54.81	16.19
			11.50	58.40	56.92	17.08
			14.50	42.80	52.59	23.31
			24.50	26.10	54.19	38.22

			9.50	65.90	53.06	15.14
			11.50	45.50	44.34	21.92
			14.50	32.10	39.44	31.07
			19.50	24.30	40.16	41.05
7.00	4.20	10.00	10.50	111.00	98.77	8.99
			11.50	88.00	85.76	11.34
			14.50	55.20	67.83	18.07
			24.50	25.40	52.74	39.27
7.00	4.20	20.00	12.50	55.40	58.69	18.01
			14.50	52.00	63.90	19.18
			19.50	31.10	51.39	32.07
			24.50	23.80	49.42	41.91
SAMPLE 7						
7.00	2.80	10.00	4.50	81.10	30.93	12.30
			5.50	72.10	33.61	13.83
			6.50	44.40	24.46	22.47
			9.50	32.70	26.33	30.50
			14.50	28.60	35.14	34.88
7.00	2.80	20.00	4.50	76.90	29.33	12.97
			5.50	50.10	23.35	19.91
			6.50	49.90	27.49	19.99
			7.50	48.70	30.95	20.48
			9.50	35.60	28.66	28.02
			11.50	25.90	25.24	38.51
7.00	3.30	0.00	4.50	94.60	36.08	10.54
			5.50	82.90	38.64	12.03
			6.50	78.50	43.24	12.71
			9.50	47.80	38.48	20.87
			14.50	29.60	36.37	33.70
			19.50	22.80	37.68	43.75
7.00	3.30	15.00	4.50	86.10	32.83	11.59
			5.50	73.20	34.12	13.63
			6.50	47.60	26.22	20.96
			7.50	41.70	26.50	23.92
			9.50	36.00	28.98	27.71
			14.50	26.70	32.81	37.36
7.00	3.60	10.00	6.50	68.70	37.84	14.52
			7.50	51.60	32.80	19.33
			9.50	41.90	33.73	23.81
			14.50	33.50	41.17	29.78
			19.50	23.50	38.83	42.45
7.00	3.60	20.00	4.50	127.90	48.78	7.80
			5.50	82.20	38.31	12.14
			6.50	64.00	35.25	15.59
			7.50	45.50	28.92	21.92
			9.50	34.50	29.39	27.33

7.00	3.90	0.00	7.50	98.20	62.42	10.16
			8.50	74.60	53.74	13.37
			9.50	65.30	52.57	15.28
			14.50	40.60	49.89	24.57
			24.50	22.80	47.34	43.75
7.00	3.90	15.00	6.50	84.50	46.55	11.80
			7.50	70.50	44.81	14.15
			9.50	54.60	43.96	18.27
			14.50	33.60	41.29	29.69
			19.50	23.30	38.50	42.81
7.00	4.20	10.00	7.50	86.50	54.98	11.53
			8.50	68.20	49.13	14.63
			9.50	59.40	47.82	16.79
			14.50	32.90	40.43	30.32
			24.50	20.90	43.39	47.73
7.00	4.20	20.00	6.50	110.30	60.76	9.04
			7.50	93.20	59.24	10.70
			8.50	59.90	43.15	16.65
			9.50	47.00	37.84	21.22
			14.50	36.00	44.24	27.71
			24.50	20.30	42.15	49.14

NEW BRUNSWICK PEAT

SIZE (MM)	SLURRY (% SOLIDS)	TEMP (C)	LOAD P (GRAMS)	TIME (SECS)	APP VISC (CPS)	nPER VEL Vr (CM/SEC)
SAMPLE 1						
4.00	2.80	10.00	24.50	108.20	224.65	9.22
			34.50	68.30	199.69	14.60
			44.50	48.10	181.39	20.74
			54.50	36.30	167.66	27.48
			74.50	21.60	136.37	46.18
4.00	3.30	10.00	44.50	108.20	408.04	9.22
			54.50	76.10	351.48	13.11
			64.50	70.30	384.27	14.19
			74.50	49.40	311.89	20.19
			104.50	27.70	245.31	36.01
4.00	3.60	10.00	74.50	92.40	583.37	10.80
			84.50	65.50	469.05	15.23
			104.50	54.60	483.53	18.27
			124.50	37.20	392.49	26.81
			154.50	27.50	360.06	36.27
4.00	3.90	10.00	84.50	81.00	580.04	12.31
			94.50	73.60	589.42	13.55
			104.50	58.80	520.73	16.96
			124.50	38.80	409.37	25.71
			154.50	27.80	363.99	35.88
4.00	4.20	10.00	154.50	86.40	1131.25	11.55
			174.50	56.50	835.53	17.65
			204.50	43.30	750.41	23.04
			254.50	32.20	694.48	30.98
			304.50	21.90	565.13	45.55
7.00	2.80	10.00	54.50	96.60	446.16	10.33
			64.50	73.10	399.57	13.65
			74.50	54.80	345.98	18.20
			104.50	40.10	355.12	24.88
			154.50	20.10	263.17	49.63
7.00	3.30	10.00	94.50	84.80	679.12	11.76
			104.50	75.90	672.17	13.14
			154.50	45.50	595.74	21.92
			204.50	29.50	511.25	33.81
			254.50	25.10	541.35	39.74
7.00	3.60	10.00	154.50	60.60	793.45	16.46
			204.50	45.30	785.07	22.02
			254.50	43.30	933.89	23.04
			300.50	29.00	738.52	34.40
			354.50	24.70	742.05	40.38
7.00	3.80	10.00	204.50	60.00	1039.93	16.63

			254.50	43.70	942.51	22.83
			304.50	41.10	1060.59	24.27
			354.50	36.10	1084.53	27.63
			454.50	26.90	1036.11	37.08
7.00	4.20	10.00	354.50	47.20	1418.00	21.13
			454.50	36.40	1402.02	27.40
			554.50	33.70	1583.61	29.60
			654.50	26.60	1475.40	37.50
SAMPLE 3						
7.00	2.80	10.00	11.50	110.40	107.59	9.04
			14.50	65.40	80.36	15.25
			19.50	37.70	62.30	26.46
			24.50	32.50	67.48	30.69
			34.50	23.10	67.54	43.18
7.00	3.30	10.00	24.50	106.30	220.71	9.38
			34.50	64.90	169.75	15.37
			44.50	42.80	161.41	23.31
			54.50	29.20	134.86	34.16
			64.50	20.80	113.69	47.96
7.00	3.60	10.00	44.50	64.50	243.24	15.47
			54.50	59.90	276.66	16.65
			64.50	31.90	174.37	31.27
			74.50	28.60	180.57	34.88
			84.50	17.90	128.18	55.73
7.00	3.90	10.00	74.50	50.20	316.94	19.87
			84.50	46.70	334.42	21.36
			104.50	33.60	297.56	29.69
			154.50	23.70	310.31	42.09
7.00	4.20	10.00	104.50	55.10	487.96	18.10
			134.50	44.40	506.08	22.47
			154.50	37.30	488.38	26.74
			174.50	24.20	357.87	41.22
			204.50	21.60	374.34	46.18
SAMPLE 4						
4.00	2.80	10.00	19.50	76.30	126.09	13.07
			24.50	59.40	123.33	16.79
			34.50	46.50	135.95	21.45
			44.50	40.10	151.22	24.86
			54.50	23.40	108.08	42.63
4.00	3.30	10.00	34.50	117.90	344.71	8.46
			44.50	61.40	231.55	16.25
			54.50	51.20	236.47	19.48
			74.50	32.00	202.03	31.17
			104.50	25.70	227.60	38.81

4.00	3.60	10.00	54.50	112.40	519.14	8.87
			84.50	50.80	363.78	19.64
			104.50	44.50	394.09	22.42
			154.50	28.80	377.08	34.64
			204.50	19.80	343.14	50.38
4.00	3.90	10.00	74.50	109.90	693.86	9.09
			84.50	62.80	449.71	15.88
			104.50	47.30	418.89	21.09
			154.50	32.10	420.29	31.07
			204.50	21.30	369.14	46.83
4.00	4.20	10.00	84.50	78.90	565.00	12.64
			104.50	60.20	533.13	16.57
			154.50	42.80	560.39	23.31
			204.50	29.80	516.45	33.47
			254.50	20.10	433.51	49.63
7.00	2.80	10.00	44.50	86.20	325.08	11.57
			54.50	60.40	278.97	16.51
			64.50	42.10	230.12	23.69
			74.50	34.90	220.34	28.58
			104.50	27.80	246.19	35.88
7.00	3.30	10.00	54.50	73.20	338.08	13.63
			74.50	56.30	355.45	17.72
			84.50	48.30	345.88	20.65
			104.50	32.70	289.59	30.50
			154.50	25.30	331.26	39.43
7.00	3.60	10.00	84.50	63.30	453.29	15.76
			104.50	49.30	436.60	20.23
			154.50	44.40	581.34	22.47
			184.50	26.70	417.47	37.36
			204.50	24.90	431.53	40.06
7.00	3.90	10.00	154.50	69.80	913.91	14.29
			174.50	42.30	625.54	23.58
			204.50	39.90	691.49	25.00
			254.50	29.60	638.41	33.70
			304.50	25.70	663.19	38.81
7.00	4.20	10.00	304.50	49.50	1277.35	20.15
			354.50	41.40	1243.75	24.09
			404.50	39.30	1347.19	25.38
			454.50	28.50	1097.73	35.00
			554.50	22.40	1052.61	44.53
SAMPLE 5						
7.00	2.80	10.00	19.50	89.30	147.57	11.17
			24.50	56.90	118.14	17.53
			34.50	35.80	104.67	27.86

			44.50	26.40	99.56	37.78
7.00	3.30	10.00	34.50	87.20	254.95	11.44
			44.50	57.10	215.33	17.47
			54.50	51.80	239.25	19.26
			64.50	34.60	189.13	28.83
			74.50	27.70	174.89	36.01
7.00	3.60	10.00	74.50	54.00	340.93	18.47
			84.50	48.70	348.74	20.48
			94.50	37.40	299.52	26.67
			104.50	33.20	294.02	30.05
			154.50	19.10	250.08	52.23
7.00	3.90	10.00	84.50	66.70	477.64	14.96
			104.50	47.60	421.54	20.96
			124.50	36.30	383.00	27.48
			154.50	27.20	356.14	36.67
			204.50	20.50	355.28	48.66
7.00	4.20	10.00	104.50	69.70	617.26	14.31
			124.50	58.30	615.11	17.11
			154.50	41.20	539.44	24.21
			204.50	29.80	516.45	33.47
			254.50	18.50	399.00	53.92
SAMPLE 6						
7.00	2.80	10.00	24.50	71.20	147.83	14.01
			29.50	42.00	105.00	23.75
			34.50	35.00	102.33	28.50
			44.50	22.30	94.10	44.73
			54.50	20.00	92.37	49.88
7.00	3.30	10.00	11.50	78.90	76.89	12.64
			14.50	51.40	63.16	19.41
			19.50	38.70	63.95	25.78
			24.50	30.20	62.70	33.03
			29.50	23.00	57.50	42.37
7.00	3.60	10.00	54.50	33.40	154.26	29.87
			64.50	27.50	150.32	36.27
			74.50	19.80	125.01	50.38
7.00	3.90	10.00	54.50	45.20	208.76	22.07
			64.50	39.90	218.10	25.00
			74.50	36.80	232.34	27.11
			84.50	21.20	151.81	47.05
7.00	4.20	10.00	64.50	41.40	226.30	24.09
			74.50	39.20	247.49	25.45
			84.50	19.80	141.79	50.38

SASKATCHEWAN PEAT

SIZE (MM)	SLURRY (% SOLIDS)	TEMP (C)	LOAD P (GRAMS)	TIME (SECS)	APP VISC (CPS)	nPER VEL Vr (CM/SEC)
SAMPLE 1						
7.00	2.80	10.00	4.50	88.10	33.60	11.32
			6.50	60.70	33.44	16.43
			9.50	46.30	37.28	21.54
			14.50	28.80	35.39	34.64
			19.50	21.50	35.53	46.40
7.00	3.30	10.00	4.50	89.70	34.21	11.12
			6.50	72.30	39.83	13.80
			9.50	47.30	38.08	21.09
			14.50	30.00	36.86	33.25
			19.50	26.40	43.63	37.78
7.00	3.60	10.00	4.50	124.40	47.44	8.02
			6.50	76.10	41.92	13.11
			9.50	50.80	40.90	19.64
			14.50	32.90	40.43	30.32
			19.50	28.70	47.43	34.76
7.00	3.90	10.00	6.50	83.90	46.22	11.89
			9.50	52.60	42.35	18.96
			14.50	38.50	47.31	25.91
			19.50	30.30	50.07	32.92
			24.50	22.50	46.72	44.33
7.00	4.20	10.00	6.50	101.50	55.91	9.83
			9.50	81.80	65.86	12.19
			14.50	38.20	46.94	26.11
			19.50	36.50	60.32	27.33
			24.50	25.10	52.11	39.74
SAMPLE 2						
7.00	2.80	10.00	6.50	97.30	53.60	10.25
			9.50	54.00	43.47	18.47
			11.50	46.70	45.51	21.36
			14.50	31.90	39.20	31.27
			19.50	26.60	43.96	37.50
7.00	3.30	10.00	14.50	96.40	118.46	10.35
			16.50	71.00	99.28	14.05
			19.50	57.10	94.36	17.47
			21.50	40.00	72.88	24.94
			24.50	28.80	59.80	34.64
7.00	3.60	10.00	16.50	114.80	160.53	8.69
			19.50	57.60	95.19	17.32
			21.50	52.90	96.39	18.86

			34.50	26.00	76.02	38.37
7.00	3.90	10.00	24.50	97.70	202.85	10.21
			29.50	56.60	141.50	17.62
			34.50	46.70	136.54	21.36
			44.50	37.30	140.67	26.74
			54.50	23.80	109.92	41.91
7.00	4.20	10.00	34.50	72.30	211.39	13.80
			39.50	60.00	200.85	16.63
			44.50	44.60	168.19	22.37
			54.50	31.10	143.64	32.07
			64.50	26.30	143.76	37.93
SAMPLE 3						
7.00	2.80	10.00	6.50	80.60	44.40	12.38
			9.50	64.50	51.93	15.47
			14.50	41.80	51.36	23.86
			19.50	32.10	53.05	31.07
			24.50	23.20	48.17	43.00
7.00	3.30	10.00	16.50	68.10	95.22	14.65
			19.50	59.40	98.16	16.79
			21.50	53.50	97.48	19.64
			24.50	39.10	81.18	25.51
			34.50	20.80	60.81	47.96
7.00	3.60	10.00	19.50	84.00	138.81	11.88
			24.50	76.50	158.83	13.04
			29.50	39.80	99.50	25.06
			34.50	29.90	87.42	33.36
			44.50	20.90	78.82	47.73
7.00	3.90	10.00	29.50	91.00	227.50	10.96
			34.50	71.10	207.88	14.03
			39.50	56.80	190.14	17.56
			44.50	38.60	145.57	25.84
			54.50	26.40	121.93	37.78
7.00	4.20	10.00	44.50	88.30	333.00	11.30
			54.50	72.00	332.54	13.85
			64.50	51.80	283.14	19.26
			74.50	36.70	231.71	27.18
			94.50	23.40	187.40	42.63

APPENDIX F

COMPUTER PROGRAM FOR CALCULATION OF PUMPING AND PIPELINE PARAMETERS

F.1 COMPUTER PROGRAM FOR CALCULATION OF PUMPING AND PIPELINING PARAMETERS

F11 DESCRIPTION OF PROGRAM

A computer program was developed by Monenco to speed the calculations described in Part 4.4. The programming language used was "BASIC" and a "RAINBOW 100" microcomputer was used for programming. The operating system was "MS-DOS". The programs do not contain any machine-specific codes, therefore they are transportable within the limitations of the BASIC language.

Two programs were developed to handle the two methods of calculation as described in Section 4.4 called "PEATSL1" and PEATSL2" and used for Method 'A' and Method 'B', respectively. Two example calculations are described in sections F12 and F13 and the program listing is included in section F14.

The input data for each problem can be stored (saved) on a disk for future use. No special knowledge in computer programming is required to run the programs.

Running the Program

After starting up the computer (using MS-DOS) and running the BASIC86 interpreter, type;

RUN "PEATSL1" RETURN

The following "MENU" appears on the display:

```
                                MENU
(1) GET DATA
(2) SAVE DATA
(3) CHANGE DATA
(4) RUN METHOD 1
(5) RUN METHOD 2
(6) END
```

- GET DATA will retrieve the input data saved previously;

- SAVE DATA will save the input data for future use;

- CHANGE DATA will allow the user to enter new input data or change the existing input data;

- RUN METHOD 1 runs the calculation method 1;

- RUN METHOD 2 runs the calculation method 2; and

- END will stop the execution of the program.

If item (3) is selected to change the data, the following will be displayed:

```
(0) TO EXIT
(1) PIPE DIAMETER, m : 0      (2) FLOW RATE, m3/hr : 0
(3) DAYS :  0 (4) EFFICIENCY : 0
(5) UTILITY FACTOR : 0        (6) BOTTOM CL'E ,m : 0
(7) MOISTURE % : 0            (8) SEASONAL PIT PASS ,m : 0
(9) PIT WIDTH ,m : 0          (10) LJ ,m : 0
(11) LCRIT ,m : 0
(12) LASSUMED INPUT
(13) PUMP CURVE INPUT
(14) VISCOSITY INPUT
```

To enter data, type the selection code 1 through 14 and RETURN . To exit to the main menu press 0 , RETURN . To enter Lassumed, pump curve and viscosity data type 12 or 13 or 14 respectively, followed by RETURN .

The following display appears for the entries:

ASSUMED LENGTH INPUT :

⟨0⟩ TO EXIT
⟨ 1 ⟩ 0
⟨ 2 ⟩ 0
⟨ 3 ⟩ 0
⟨ 4 ⟩ 0

PUMP DATA INPUT :

PRINT ⟨0⟩ TO EXIT

	HEAD	Q
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
8	0	0

VISCOSITY INPUT :

(0) TO EXIT

	SOLIDS CONT %			
(1)	0			
(2)	0			
(3)	0			
(4)	0			
	0	0	0	0
(5) 0	0	0	0	0
(6) 0	0	0	0	0
(7) 0	0	0	0	0
(8) 0	0	0	0	0
(9) 0	0	0	0	0
(10) 0	0	0	0	0
(11) 0	0	0	0	0
(12) 0	0	0	0	0
(13) 0	0	0	0	0
(14) 0	0	0	0	0
(15) 0	0	0	0	0
(16) 0	0	0	0	0

F12 EXAMPLE CALCULATION METHOD 'A'

The following includes a typical example calculation for a pump/pipeline system, using the "PEATSL1" program.

****

MONENCO PEAT GROUP
PEAT SLURRY PUMPING
METHOD 1

****

INPUT PARAMETERS :

PUMP DATA :

HEAD	DISCHARGE
m	m3/hr
26	100
24.7	200
22.2	400
19.5	600
19	650
16	800
12	1000
0	0

LAB VISCOMETER DATA :

SOLIDS CONTENT %	3.3	3.6	3.9	4.2
VELOCITY,cm/sec		VISCOSITY,POISE		
2	5.15	7.4	9.899999	11.85
3	4.27	6.05	8.42	10
4	3.6	5.16	7.25	8.7
5	3.12	4.47	6.37	7.62
6	2.75	3.9	5.75	6.85
7	2.45	3.53	5.25	6.25
8	2.2	3.2	4.8	5.75
9	2	2.96	4.4	5.27
10	1.85	2.75	4	4.85
12	1.65	2.45	3.5	4.2
14	1.55	2.16	3.15	3.8

OPERATION DAYS = 110
UTILIZATION FACTOR = .9
EFFICIENCY = .9
BOTTOM CLEARANCE = .3 m
PEAT MOISTURE = 89 %
AVG HEIGHT OF SEASONAL PIT PASS = 2.5 m
AVG WIDTH OF SEASONAL PIT PASS = 170 m
L j = 225 m
L crit = 850 m
PIPE DIAMETER = .438 m
DISCHARGE RATE = 585 m3/hr

CALCULATION RESULTS :

AVERAGE VELOCITY = 1.08 m/s
VISCOMETER VELOCITY = 8.74 cm/s
SEASONAL DISCHARGE RATE = 1389960 m3
PUMP HEAD = 19.7025 m

	A	ETA	ETA'	WATER ADD COEFF
1	.19	2.03	2.05	2.35
2	.15	1.52	3.02	2.59
3	.12	1.22	4.51	2.79
4	.1	1.02	5.4	2.96

	SOL CONT, %	Lassumed	Ldesign	Lpass
1	3.28	750	1153	1231
2	3.06	1000	1112	1149
3	2.9	1250	1082	1090
4	2.78	1500	1059	1043

OPTIMUM VALUES :
SOLIDS CONCENTRATION = 3 %
L pass = 1125 m (seasonal pit)
L des = 1100 m
Water Add. Coeff = 2.67

The pump head must be expressed in meters, the discharge rate in m^3/hr, the assumed length in meters, and the viscosity in poise. In the viscosity input display, the number immediately following the selection number is the viscometer velocity in cm/sec.

For the Method "B" calculations the input is exactly the same with the following exceptions:

- the assumed length is deleted; and
- the pump performance curve is replaced with an assumed pumping curve.

F13 EXAMPLE CALCULATION METHOD "B"

The following includes a typical example calculation for a pump/pipeline system, using the "PEATSL2" program.

****

MONENCO PEAT GROUP
PEAT SLURRY PUMPING
METHOD 2

****

INPUT PARAMETERS :

ASSUMED PUMP DATA :

HEAD	DISCHARGE
m	m3/hr
21.6	450
19.5	600
17	750
13.8	900

LAB VISCOMETER DATA :

SOLIDS CONTENT %	3.3	3.6	3.9	4.2
VELOCITY,cm/sec		VISCOSITY,POISE		
2	5.15	7.4	9.099999	11.05
3	4.27	6.05	8.42	10
4	3.6	5.16	7.25	8.7
5	3.12	4.47	6.37	7.62
6	2.75	3.9	5.75	6.85
7	2.45	3.53	5.25	6.25
8	2.2	3.2	4.8	5.75
9	2	2.96	4.4	5.27
10	1.85	2.75	4	4.85
12	1.65	2.45	3.5	4.2
14	1.55	2.16	3.15	3.8

OPERATION DAYS = 110
UTILIZATION FACTOR = .9
EFFICIENCY = .9
BOTTOM CLEARANCE = .3 m
PEAT MOISTURE = 89 %
AVG HEIGHT OF SEASONAL PIT PASS = 2.5 m
AVG WIDTH OF SEASONAL PIT PASS = 170 m
L tot = 1100 m
PIPE DIAMETER = .438 m

CALCULATION RESULTS :

	AVG VEL m/s	VISC VEL cm/s	A	ETA poise	SOL CONT %	ETA' poise
1	.83	6.72	.25	1.98	3.3	2.53
					3.6	3.63
					3.9	5.39
					4.2	6.42
2	1.11	8.96	.12	1.34	3.3	2.01
					3.6	2.97
					3.9	4.42
					4.2	5.29
3	1.38	11.2	.07	.93	3.3	1.73
					3.6	2.57
					3.9	3.7
					4.2	4.46
4	1.66	13.44	.04	.63	3.3	1.38
					3.6	2.24
					3.9	3.25
					4.2	3.91

	SOL CONT, %	PUMP YIELD (*)	FLOW RATE,m3/hr
1	3.09	27.8421	450
2	2.98	35.78635	600
3	2.82	42.27738	750
4	2.6	46.84022	900

(*) TONNES OF 50% m.c. PEAT

F14 PROGRAM LISTING

```
100 DIM CCAL(4),LPAS(4),WC(4),LDES(4),VISC(18,14),PUMP(2,8),CM(18),A(4),CSL(4),
110 E$="<0> TO EXIT"
112 L$=CHR$(27)+CHR$(91)+CHR$(56)+CHR$(119):S$=CHR$(27)+CHR$(91)+CHR$(52)+CHR$(1
113 LPRINT S$
115 DEF FNY0(X)=INT((X*10+5)/10)
116 DEF FNY2(X)=INT((X*1000+5)/10)/100
120 PRINT:PRINT:PRINT:PRINT,,"MENU":PRINT"<1> GET DATA":PRINT"<2> SAVE DATA":PRI
> RUN METHOD 2":PRINT"<6> END"
130 INPUT I: IF I<1 OR I>6 THEN GOTO 120
135 ON I GOTO 770,850,300,2000,140,150
140 RUN "PEATSL2"
150 END
300 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT" PEAT SLURRY PUMPING CALCULA
T E$
305 PRINT"<1> PIPE DIAMETER, m :";D,"<2> FLOW RATE, m3/hr :";Q
307 PRINT"<3> DAYS : ";DAYS,"<4> EFFICIENCY :";EFF:PRINT"<5> UTILITY FACTOR :";U
309 PRINT"<7> MOISTURE % :";MOIST,"<8> SEASONAL PIT PASS ,m :";H
311 PRINT"<9> PIT WIDTH ,m :";B,"<10> LJ ,m :";LJ:PRINT"<11> LCRIT ,m :";LCRIT:P
T"
313 PRINT"<14> VISCOSITY INPUT"
320 INPUT I:IF I=0 THEN GOTO 120
325 IF I<1 OR I>14 THEN GOTO 300
330 ON I GOTO 400,405,410,415,420,425,430,435,440,445,450,500,550,600
400 INPUT D: GOTO 300
405 INPUT Q:GOTO 300
410 INPUT DAYS:GOTO 300
415 INPUT EFF:GOTO 300
420 INPUT UTFAC:GOTO 300
425 INPUT BOTHT:GOTO 300
430 INPUT MOIST:GOTO 300
435 INPUT H:GOTO 300
440 INPUT B:GOTO 300
445 INPUT LJ:GOTO 300
450 INPUT LCRIT:GOTO 300
500 PRINT:PRINT:PRINT:PRINT "ASSUMED LENGTH INPUT :":PRINT:PRINT:PRINT E$
505 FOR I=1 TO 4:PRINT"<";I;">";LAS(I):NEXT
510 INPUT A
515 IF A=0 THEN GOTO 300
517 IF A<1 OR A>4 THEN GOTO 500
520 INPUT LAS(A):GOTO 500
550 PRINT:PRINT:PRINT:PRINT"PUMP DATA INPUT : ":PRINT:PRINT:PRINT:PRINT
552 PRINT"PRINT <0> TO EXIT"
555 PRINT,"HEAD","Q":PRINT,"m","m3/hr"
560 FOR I=1 TO 8:PRINT I,PUMP(1,I),PUMP(2,I):NEXT
580 INPUT "ROW #";A
581 IF A=0 THEN GOTO 300
582 IF A<1 OR A>8 THEN GOTO 580
585 INPUT"HEAD,Q";PUMP(1,A),PUMP(2,A):GOTO 550
600 PRINT:PRINT:PRINT:PRINT:PRINT"VISCOSITY INPUT :":PRINT:PRINT E$
```

```
610 PRINT,"SOLIDS CONT %"
615 FOR I=1 TO 4:PRINT"<";I;">",SCN(I):NEXT
617 PRINT:PRINT,SCN(1),SCN(2),SCN(3),SCN(4):PRINT
620 FOR I=1 TO 12:PRINT"<";I+4;">";TAB(9);CM(I),VISC(I,1),VISC(I,2),VISC(I,3),VI
630 INPUT I:IF I=0 THEN GOTO 300
640 IF I<1 OR I>18 THEN GOTO 600
645 IF I<5 THEN INPUT SCN(I):GOTO 600
650 IF I>4 THEN I=I-4:INPUT CM(I),VISC(I,1),VISC(I,2),VISC(I,3),VISC(I,4):GOTO 6
770 INPUT "ENTER FILE NAME";A$
775 OPEN "I",1,A$
780 FOR I=1 TO 4: INPUT#1, LAS(I): NEXT :INPUT#1, NC
790 FOR I=1 TO 8
795 INPUT#1, PUMP(1,I),PUMP(2,I)
800 NEXT
805 FOR I=1 TO NC: INPUT#1, CM(I) : NEXT
810 FOR J=1 TO 4: INPUT#1, SCN(J)
815 FOR I=1 TO NC: INPUT#1, VISC (I,J)
820 NEXT
825 NEXT
830 INPUT#1,D,Q,DAYS,EFF,UTFAC,BOTHT,MOIST,H,B,LJ,LCRIT,X
835 CLOSE :GOTO 120
850 INPUT "ENTER FILE NAME";A$
855 OPEN "O",1,A$
860 FOR I=1 TO 4: PRINT#1, LAS(I): NEXT :PRINT#1, NC
865 FOR I=1 TO 8
870 PRINT#1, PUMP(1,I),PUMP(2,I)
875 NEXT
880 FOR I=1 TO NC: PRINT#1, CM(I) : NEXT
885 FOR J=1 TO 4: PRINT#1, SCN(J)
890 FOR I=1 TO NC: PRINT#1, VISC (I,J)
895 NEXT
900 NEXT
905 PRINT#1,D,Q,DAYS,EFF,UTFAC,BOTHT,MOIST,H,B,LJ,LCRIT,X
910 CLOSE : GOTO 120
2000 VAVG=4*Q/3600/3.14159/D^2
2010 VVISC=8.100001*VAVG
2100 REM CALC PUMP HEAD
2110 I=1
2120 IF Q>PUMP(2,I) AND Q<=PUMP(2,I+1) THEN GOTO 2150
2130 I=I+1 : GOTO 2120
2150 FARK=(Q-PUMP(2,I))/(PUMP(2,I+1)-PUMP(2,I))
2160 HEAD= PUMP(1,I)-FARK*(PUMP(1,I)-PUMP(1,I+1))
2200 FOR I= 1 TO 4
2210 A(I)= HEAD*D*9.810001/VAVG^2/LAS(I)*2
2220 ETA(I)=A(I)*D^2*VVISC/.16
2230 NEXT
2255 J=1
2260 IF VVISC>CM(J) AND VVISC<= CM(J+1) THEN GOTO 2280
2270 J=J+1:GOTO 2260
2280 FARK=(VVISC-CM(J))/(CM(J+1)-CM(J))
2285 FOR I=1 TO 4
2290 CSL(I)=VISC(J,I)-FARK*(VISC(J,I)-VISC(J+1,I))
2297 NEXT
2298 FOR I=1 TO 4:Y(I)=SCN(I):X(I)=CSL(I):NEXT :GOSUB 3000
2300 FOR I=1 TO 4:CCAL(I)=C1*ETA(I)^C2
2310 NEXT
2350 QSES=Q*24*DAYS*EFF
2355 FOR I=1 TO 4
2360 WC(I)=((100-MOIST)-CCAL(I))/CCAL(I)
2365 LPAS(I)=QSES/(1+WC(I))/B/UTFAC/(H-BOTHT)
2370 LDES(I)=(LPAS(I)+LJ+LCRIT)/2
2375 NEXT
```

```
2400 FLAG=0:X=0:X1=0
2410 FOR I=1 TO 4
2420 X=LAS(I)-LDES(I):PRINT X:IF I=1 THEN GOTO 2428
2425 IF SGN(X1)=SGN(X) THEN GOTO 2430 :ELSE GOTO 2440
2428 X1=X
2430 NEXT
2435 IF FLAG=0 THEN FOR I=1 TO 4:LAS(I)=LAS(I)*1.1:NEXT:PRINT"WARNING : Lassumed
2440 M1=(LAS(I)-LAS(I-1))/(CCAL(I)-CCAL(I-1))
2445 M2=(LDES(I)-LDES(I-1))/(CCAL(I)-CCAL(I-1))
2450 B1=LAS(I)-M1*CCAL(I):B2=LDES(I)-M2*CCAL(I)
2460 SOLOPT=(B2-B1)/(M1-M2)
2465 WOPT=((100-MOIST)-SOLOPT)/SOLOPT
2470 LOPT=QSES/(1+WOPT)/B/UTFAC/(H-BOTHT)
2475 LN=M1*SOLOPT+B1
2999 GOTO 5800
3000 X0=0:X1=0:X2=0:X3=0
3010 FOR I=1 TO 4
3020 X0=X0+LOG(X(I)):X1=X1+LOG(X(I))*LOG(Y(I)):X2=X2+LOG(Y(I)):X3=X3+(LOG(X(I)))
3030 NEXT
3040 C2=(X1-X0*X2/4)/(X3-X0*X0/4):C1=EXP(X2/4-C2*X0/4)
3050 RETURN
5800 LPRINT,,:FOR I=0 TO 60:LPRINT "*";:NEXT
5825 LPRINT L$:LPRINT,"      MONENCO PEAT GROUP"
5826 LPRINT ,"      PEAT SLURRY PUMPING"
5828 LPRINT ,"           METHOD  1"
5850 LPRINT S$
5860 LPRINT,,:FOR I=0 TO 60:LPRINT "*";:NEXT
5870 LPRINT :LPRINT :LPRINT"L$:LPRINT ,"INPUT PARAMETERS :":LPRINT :LPRINT S$
6000 LPRINT ,"PUMP DATA  :"
6010 LPRINT ,"HEAD","DISCHARGE":LPRINT ,"  m"," m3/hr"
6020 FOR I=1 TO 8:LPRINT, PUMP(1,I),PUMP(2,I):NEXT:LPRINT  " ":LPRINT
6100 LPRINT"LAB VISCOMETER DATA :"
6120 LPRINT "SOLIDS CONTENT %",:FOR I=1 TO 4:LPRINT SCN(I),:NEXT:LPRINT
6130 LPRINT "VELOCITY,cm/sec",,"VISCOSITY,POISE"
6140 FOR I=1 TO NC:LPRINT CM(I),,
6150 FOR J=1 TO 4:LPRINT FN Y2(VISC(I,J)),:NEXT:LPRINT :NEXT:LPRINT :LPRINT
6160 LPRINT "OPERATION DAYS =";DAYS:LPRINT "UTILIZATION FACTOR =";UTFAC:LPRINT"E
m"
6162 LPRINT "PEAT MOISTURE =";MOIST;"%":LPRINT "AVG HEIGHT OF SEASONAL PIT PASS
6164 LPRINT "AVG WIDTH OF SEASONAL PIT PASS =";B;"m"
6166 LPRINT "L j =";LJ;"m":LPRINT "L crit =";LCRIT;"m"
6200 LPRINT "PIPE DIAMETER =";D;"m":LPRINT "DISCHARGE RATE =";Q;"m3/hr"
6205 LPRINT:LPRINT:LPRINT:LPRINT:LPRINT L$,"CALCULATION RESULTS :":LPRINT S$:LPR
6210 LPRINT "AVERAGE VELOCITY =";FN Y2(VAVG);"m/s":LPRINT "VISCOMETER VELOCITY =
6215 LPRINT "SEASONAL DISCHARGE RATE =";QSES;"m3"
6220 LPRINT "PUMP HEAD = ";HEAD;"m":LPRINT :LPRINT
6240 LPRINT , "  A", " ETA", " ETA'      WATER ADD COEFF"
6250 FOR I=1 TO 4:LPRINT I,FN Y2(A(I)),FN Y2(ETA(I)),FN Y2(CSL(I)),FN Y2(WC(I)):
6300 LPRINT :LPRINT
6310 LPRINT , "SOL CONT, %","Lassumed","Ldesign","Lpass"
6320 FOR I=1 TO 4:LPRINT I,FN Y2(CCAL(I)),LAS(I),FN Y0(LDES(I)),FN Y0(LPAS(I)):N
6340 LPRINT ,"OPTIMUM VALUES :"
6345 LPRINT "SOLIDS CONCENTRATION =";FN Y2(SOLOPT);"%"
6350 LPRINT "L pass =";FN Y0(LOPT);"m   (seasonal pit)"
6375 LPRINT "L des =";FN Y0(LN);"m"
6380 LPRINT "Water Add. Coeff =";FN Y2(WOPT)
6400 GOTO 120
```

```
100 DIM Z(4),VAVG(4),VVISC(4),CCAL(4),LPAS(4),WC(4),LDES(4),VISC(18,14),PUMP(2,8
110 E$="<0> TO EXIT"
112 L$=CHR$(27)+CHR$(91)+CHR$(56)+CHR$(119):S$=CHR$(27)+CHR$(91)+CHR$(52)+CHR$(1
113 LPRINT S$
115 DEF FNY0(X)=INT((X*10+5)/10)
116 DEF FNY2(X)=INT((X*1000+5)/10)/100
120 PRINT:PRINT:PRINT:PRINT,,"MENU":PRINT"<1> GET DATA":PRINT"<2> SAVE DATA":PRI
> RUN METHOD 2":PRINT"<6> END"
130 INPUT I: IF I<1 OR I>6 THEN GOTO 120
135 ON I GOTO 770,850,300,140,2000,150
140 RUN "PEATSL1"
150 END
300 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT" PEAT SLURRY PUMPING CALCULA
T E$
305 PRINT"<1> PIPE DIAMETER, m :";D
307 PRINT"<2> DAYS : ";DAYS,"<3> EFFICIENCY :";EFF:PRINT"<4> UTILITY FACTOR :";U
309 PRINT"<6> MOISTURE % :";MOIST,"<7> SEASONAL PIT PASS ,m :";H
311 PRINT"<8> PIT WIDTH ,m :";B:PRINT"<11> L assumed ,m =";LAS:PRINT"<12> ASSUME
313 PRINT"<13> VISCOSITY INPUT"
320 INPUT I:IF I=0 THEN GOTO 120
325 IF I<1 OR I>14 THEN GOTO 300
330 ON I GOTO 400,410,415,420,425,430,435,440,445,450,455,550,600
400 INPUT D: GOTO 300
410 INPUT DAYS:GOTO 300
415 INPUT EFF:GOTO 300
420 INPUT UTFAC:GOTO 300
425 INPUT BOTHT:GOTO 300
430 INPUT MOIST:GOTO 300
435 INPUT H:GOTO 300
440 INPUT B:GOTO 300
445 INPUT LJ:GOTO 300
450 INPUT LCRIT:GOTO 300
455 INPUT LAS:GOTO 300
550 PRINT:PRINT:PRINT:PRINT" ASSUMED PUMP DATA INPUT : ":PRINT:PRINT:PRINT:PRINT
552 PRINT"PRINT <0> TO EXIT"
555 PRINT,"HEAD","Q":PRINT,"m","m3/hr"
560 FOR I=1 TO 4:PRINT I,PUMP(1,I),PUMP(2,I):NEXT
580 INPUT "ROW #";A
581 IF A=0 THEN GOTO 300
582 IF A<1 OR A>4 THEN GOTO 580
585 INPUT"HEAD,Q";PUMP(1,A),PUMP(2,A):GOTO 550
600 PRINT:PRINT:PRINT:PRINT:PRINT"VISCOSITY INPUT :":PRINT:PRINT E$
610 PRINT,"SOLIDS CONT %"
615 FOR I=1 TO 4:PRINT"<";I;">",SCN(I):NEXT
617 PRINT:PRINT,SCN(1),SCN(2),SCN(3),SCN(4):PRINT
620 FOR I=1 TO 12:PRINT"<";I+4;">";TAB(9);CM(I),VISC(I,1),VISC(I,2),VISC(I,3),VI
630 INPUT I:IF I=0 THEN GOTO 300
640 IF I<1 OR I>18 THEN GOTO 600
645 IF I<5 THEN INPUT SCN(I):GOTO 600
650 IF I>4 THEN I=I-4:INPUT CM(I),VISC(I,1),VISC(I,2),VISC(I,3),VISC(I,4):GOTO 6
770 INPUT "ENTER FILE NAME";A$
775 OPEN "I",1,A$
780 FOR I=1 TO 4: INPUT#1, Z(I): NEXT :INPUT#1, NC
790 FOR I=1 TO 8
795 INPUT#1, PUMP(1,I),PUMP(2,I)
800 NEXT
805 FOR I=1 TO NC: INPUT#1, CM(I) : NEXT
810 FOR J=1 TO 4: INPUT#1, SCN(J)
815 FOR I=1 TO NC: INPUT#1, VISC (I,J)
```

```
820 NEXT
825 NEXT
830 INPUT#1,D,Q,DAYS,EFF,UTFAC,BOTHT,MOIST,H,B,LJ,LCRIT,LAS
835 CLOSE :GOTO 120
850 INPUT "ENTER FILE NAME";A$
855 OPEN "O",1,A$
860 FOR I=1 TO 4: PRINT#1, Z(I): NEXT :PRINT#1, NC
865 FOR I=1 TO 8
870 PRINT#1, PUMP(1,I),PUMP(2,I)
875 NEXT
880 FOR I=1 TO NC: PRINT#1, CM(I) : NEXT
885 FOR J=1 TO 4: PRINT#1, SCN(J)
890 FOR I=1 TO NC: PRINT#1, VISC (I,J)
895 NEXT
900 NEXT
905 PRINT#1,D,Q,DAYS,EFF,UTFAC,BOTHT,MOIST,H,B,LJ,LCRIT,LAS
910 CLOSE : GOTO 120
2000 FOR I=1 TO 4:VAVG(I)=4*PUMP(2,I)/3600/3.14159/D^2
2010 VVISC(I)=8.100001*VAVG(I):NEXT
2200 FOR I= 1 TO 4
2210 A(I)= PUMP(1,I)*D*9.810001/VAVG(I)^2/LAS*2
2220 ETA(I)=A(I)*D^2*VVISC(I)/.16
2230 NEXT
2240 FOR J1=1 TO 4
2255 J=1
2260 IF VVISC(J1)>CM(J) AND VVISC(J1)<= CM(J+1) THEN GOTO 2280
2270 J=J+1:GOTO 2260
2280 FARK=(VVISC(J1)-CM(J))/(CM(J+1)-CM(J))
2285 FOR I=1 TO 4
2290 CSL(I,J1)=VISC(J,I)-FARK*(VISC(J,I)-VISC(J+1,I))
2297 NEXT : NEXT
2298 FOR J=1 TO 4:FOR I=1 TO 4:Y(I)=SCN(I):X(I)=CSL(I,J):NEXT :GOSUB 3000
2300 CCAL(J)=C1*ETA(J)^C2
2310 NEXT
2350 MAX=0
2400 FOR I=1 TO 4
2410 PUYIELD(I)=PUMP(2,I)*CCAL(I)/50
2420 IF PUYIELD(I)>MAX THEN MAX=I
2430 NEXT
2999 GOTO 5800
3000 X0=0:X1=0:X2=0:X3=0
3010 FOR I=1 TO 4
3020 X0=X0+LOG(X(I)):X1=X1+LOG(X(I))*LOG(Y(I)):X2=X2+LOG(Y(I)):X3=X3+(LOG(X(I)))
3030 NEXT
3040 C2=(X1-X0*X2/4)/(X3-X0*X0/4):C1=EXP(X2/4-C2*X0/4)
3050 RETURN
5800 LPRINT,,:FOR I=0 TO 60:LPRINT "*";:NEXT
5825 LPRINT L$:LPRINT,"       MONENCO PEAT GROUP"
5826 LPRINT ,"      PEAT SLURRY PUMPING"
5828 LPRINT ,"            METHOD  2"
5850 LPRINT S$
5860 LPRINT,,:FOR I=0 TO 60:LPRINT "*";:NEXT
5870 LPRINT :LPRINT :LPRINT L$:LPRINT ,"INPUT PARAMETERS :":LPRINT :LPRINT S$
6000 LPRINT ," ASSUMED PUMP DATA  :"
6010 LPRINT ,"HEAD","DISCHARGE":LPRINT ,"  m"," m3/hr"
6020 FOR I=1 TO 4:LPRINT, PUMP(1,I),PUMP(2,I):NEXT:LPRINT  " ":LPRINT
6100 LPRINT"LAB VISCOMETER DATA :"
```

```
6120 LPRINT "SOLIDS CONTENT %",:FOR I=1 TO 4:LPRINT SCN(I),:NEXT:LPRINT
6130 LPRINT "VELOCITY,cm/sec",,"VISCOSITY,POISE"
6140 FOR I=1 TO NC:LPRINT CM(I),,
6150 FOR J=1 TO 4:LPRINT FN Y2(VISC(I,J)),:NEXT:LPRINT :NEXT:LPRINT :LPRINT
6160 LPRINT "OPERATION DAYS =";DAYS:LPRINT "UTILIZATION FACTOR =";UTFAC:LPRINT"E
m"
6162 LPRINT "PEAT MOISTURE =";MOIST;"%":LPRINT "AVG HEIGHT OF SEASONAL PIT PASS
6164 LPRINT "AVG WIDTH OF SEASONAL PIT PASS =";B;"m"
6166 LPRINT "L sug =";LAS;"m"
6200 LPRINT "PIPE DIAMETER =";D;"m"
6205 LPRINT:LPRINT:LPRINT:LPRINT:LPRINT L$,"CALCULATION RESULTS :":LPRINT S$:LPR
6240 LPRINT , "AVG VEL","VISC VEL","  A", " ETA","SOL CONT", " ETA'"
6245 LPRINT ,"  m/s","  m/s",,"poise","  %","poise"
6250 FOR I=1 TO 4:LPRINT I,FN Y2(VAVG(I)),FN Y2(VVISC(I)),FN Y2(A(I)),FN Y2(ETA(
(CSL(J,I)),:NEXT:LPRINT :NEXT
6300 LPRINT :LPRINT
6310 LPRINT , "SOL CONT, %",,"PUMP YIELD (*)"
6320 FOR I=1 TO 4:LPRINT I,FN Y2(CCAL(I)),,PUYIELD(I):NEXT:LPRINT :LPRINT
6330 LPRINT"(*) TONNES OF 50% m.c. PEAT":LPRINT :LPRINT :LPRINT
6340 LPRINT ,"OPTIMUM VALUES :"
6345 LPRINT "SOLIDS CONCENTRATION =";FN Y2(CCAL(MAX));"%"
6350 LPRINT "FLOW RATE  =";FN Y0(PUMP(2,MAX));"m3/hr"
6400 GOTO 120
```

APPENDIX G

REFERENCES, BIBLIOGRAPHY, GLOSSARY

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G.3 GLOSSARY

Peatland Type: Major division in the peatland classification system. The USSR system is composed of three types (lowmoor, highmoor, transitional moor) and the Canadian system of four types (swamp, marsh, fen, bog) called formations (cf. Formation).

Peatland Sub-Type: Peatland sub-types in the USSR system are divided into sub-types depending on whether they are treed, open or forested (forested is called swamp, others are treed and open fens, treed and open bogs). The Canadian equivalents are sub-formations (treed or open) and complemented with a further division into physiognomic groups (cf. Sub-Formation and Physiognomic Group).

Peat Type: Division of peat into types based on its botanical composition, e.g., sedge peat is a peat type composed mainly of the remnants of sedge.

Peat Group: Group of peats predominated by the same botanical constituent, e.g., moss peats contain peat with mosses predominating (e.g., sedge-sphagnum peat, shrub-sphagnum peat, etc.).

Formation: In Canadian practice, peatlands are divided into formations (swamp, bog, fen, marsh). These are equivalents of the USSR peatland types (cf. peatland type).

Sub-Formation: Formations are divided into sub-formations depending on whether they are treed or open. These are equivalent of the USSR sub-types (cf. peatland sub-types).

Physiognomic Groups: Sub-formations are further divided into physiognomic groups depending on their vegetation in detail (e.g. tall shrub treed bog).

Degree of Decomposition: The percentage of structureless (amorphous) matter (composed of humic and other microscopically unidentifiable material) of the total peat sample.

Degree of Humification: A ranking of H1 to H10 on the von Post scale signifying the degree to which peat has decomposed as determined by the von Post squeeze test by hand.

Apparent Viscosity: Viscosity measurements with the Stormer Viscometer depend entirely on the rate of flow of the substance under test with a given driving weight. Some substances, such as water, glycerol and castor oil at a given temperature, will never change their viscosity irrespective of the magnitude of the applied driving weight. However, the majority of substances, including peat, do not have a true viscosity such as that displayed by water, glycerol and castor oil, but have an apparent viscosity depending upon the applied driving weight and the resulting rate of shear of liquid under test.

Conventional Viscosity: Is apparent viscosity when the peripheral velocity of the viscometer rotating cylinder equals 15 cm/sec.

Peat Slurry Maceration: A process whereby peat slurry is further cut and mixed to a desirable consistency by knives and blades revolving at high speed in an enclosed chamber in the macerating unit of a slurry pump.

Optimal Peat Slurry Solids Content: For the given peat it is defined in the USSR source as the solids content which provides the maximum capacity of the system in terms of the peat output for the given time span.